Public Interest Energy Research (PIER) Program FINAL PROJECT REPORT

EMISSIONS AND POTENTIAL EMISSION REDUCTIONS FROM HAZARDOUS FUEL TREATMENTS IN THE WESTCARB REGION

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PREFACE

The California Energy Commission Public Interest Energy Research (PIER) Program supports public interest energy research and development that will help improve the quality of life in California by bringing environmentally safe, affordable, and reliable energy services and products to the marketplace.

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Emissions and Potential Emission Reductions From Hazardous Fuel Treatments in the WESTCARB Region is the final report for the WESTCARB Fuels Management Pilot Activities in Shasta County, California, West Coast Regional Carbon Sequestration Partnership – Phase II project, Contract Number 500-02-004, Work Authorization number MR-045 conducted by Winrock International. The information from this project contributes to PIER's Energy-Related Environmental Research Program.

For more information about the PIER Program, please visit the Energy Commission's website at www.energy.ca.gov/research/ or contact the Energy Commission at 916-327-1551.

ABSTRACT

This report summarizes efforts by Winrock International and the West Coast Regional Carbon Sequestration Partnership Fire Panel to develop a methodology for estimating greenhouse gas benefits of project activities to reduce emissions from wildland fires in low- to mid-elevation mixed conifer forests. These efforts focused on low- to mid-elevation mixed conifer forests and included a conceptual framework to aid in determining the full impacts of hazardous fuels treatments. The framework was developed based upon four workshops with carbon and fire experts, numerous consultant activities, and field measurements of hazardous fuels treatments in Shasta County, California and Lake County, Oregon. The task of developing a rigorous methodology to quantify baseline emissions from wildland fires and emission reductions attributable to fuel reduction is complex. The methodological challenges of modeling wildland fire behavior and emissions, the relatively low annual risk of fire for any given potential project location, and the emissions resulting from fuels treatments complicate the development of the methodology. Given current hazardous fuel removal technologies and the low probability of fire on any given acre in any given year, hazardous fuel reduction treatments in the forest types addressed in this report cannot directly generate offsets. However, careful design of fuel treatments built from the methodology employed in this analysis can minimize risks to lives and property while minimizing emissions

Keywords: Carbon, sequestration, emission, forest, hazardous fuel reduction, California, wildland, fire, wildfire, greenhouse gas

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EXECUTIVE SUMMARY

Introduction

The West Coast Regional Carbon Sequestration Partnership (WESTCARB), led by the California Energy Commission, is one of seven U.S. Department of Energy regional partnerships working to evaluate, validate, and demonstrate ways to sequester carbon dioxide and reduce emissions of greenhouse gases linked to global climate change. Emissions from fire were identified in WESTCARB Phase I as the single largest source of greenhouse gas emissions from land use. Thus, the focus of this research is to determine if greenhouse gas emissions from wildfires could be reduced and provide a potential opportunity for landowners to generate a new type of carbon mitigation or "offset" activity. For such activities to yield greenhouse gas offsets, rigorous measurement, monitoring and verification methodologies, and reporting protocols must be developed to meet the standards of voluntary and regulated markets for high-quality greenhouse gas reductions. Fire suppression and hazardous fuel accumulation are concerns primarily in low- to mid-elevation mixed conifer forests that prehistorically experienced frequent and low severity fires. Therefore, this analysis and its findings focused on these ecosystems, in mixed conifer forests in Northern California and Southern Oregon.

Purpose

This research aimed to determine whether a methodology could be used by developers of potential carbon projects to quantify their baseline emissions, predict emissions when activities reduce hazardous fuels, and estimate the associated project carbon benefit.

Project Objectives

The overall goal of WESTCARB Phase II is to validate and demonstrate the region's key carbon sequestration opportunities through pilot projects, methodology development, reporting, and market validation. WESTCARB research will facilitate informed decisions by policymakers, communities, and businesses on how to invest in carbon capture and storage technology development and deployment to achieve climate change mitigation objectives. The opportunity presented here is decreasing wildland fire emissions through hazardous fuel treatment, combined, where feasible, with fuel removal to a biomass energy facility.

Project Methodology

A conceptual framework was developed to determine the net effect of hazardous fuel treatment activities on the total quantity of greenhouse gases in the atmosphere. This framework incorporated the critical elements of fuel treatments and wild-land fires as they relate to net carbon dioxide (CO₂) emissions:

- Annual Fire Risk
- Emissions as a Result of Treatment
- Emissions as a Result of Fire
- Removals From Forest Growth / Regrowth
- Retreatment
- Shadow Effect

The following framework was used to estimate losses and gains in stored carbon with and without treatments and fire:

- Gain from *decreased* intensity or spread of fire due to fuel treatment within the project and shadow areas (based on annual fire probability).
- Loss from biomass removed during treatment.
- Gain /Loss from substitution of fuels for energy generation.
- Gain from long term storage of wood products from removed biomass during fuels treatment.
- Loss from decomposition of additional dead wood stocks created through fuels treatment.
- Gain /Loss from growth differences between treated and untreated, and with and without fire.
- Loss from fires occurring in treated project case (based on annual fire probability).
- Loss from retreating forest stands through time.

A positive net result indicates increased carbon storage as a result of the treated project. A negative net result indicates a net loss in carbon storage and increased emissions as a result of the treated project.

The individual elements of this framework were quantified to determine their overall impact on removal in net emissions, and on-the-ground projects were implemented to test the overall validity of the framework.

Project Outcomes

Fire represents a significantly more complex opportunity than traditional land use greenhouse gas reduction activities such as afforestation (establishing a forest), changes in forest management, and forest protection. This is because a fuel reduction project compares emissions that would have occurred from fires without any treatment on the landscape, which necessarily requires a complex fire baseline modeling effort, against emissions that did occur through fuel

treatment. For this purpose it was necessary to examine the risk of a fire burning through a particular location or fireshed in a given year and the emissions that would occur if such a fire did occur.

The reality is that fire risk in any given location on the landscape considered in this report is relatively low (< 0.76 percent per year), and consequently baseline emissions are low. This reality must be balanced with the emissions that occur when a catastrophic fire does occur. While emissions from fire in the baseline scenario are relatively low, emissions from fuel treatment in the project scenario are not insignificant in that they occur across a relatively broad area in order to intersect with an unknown future fire location.

Substantial emissions occur during a wildfire, but significant greenhouse gas emissions still occur on treated sites. In addition, regrowth of a healthy forest means that sites have to be retreated with accompanying emissions on a regular schedule (likely < 20 years). The impact of growth is complex. However, in the absence of wildfire growth modeling, these projects show that the treated stands, as a whole, will store less carbon than the untreated stands. The opposite is true in the event of a wildfire, but such a fire is a low probability event.

Consolidating across the conceptual framework, the following conclusions were reached:

- Fire risk is very low (< 0.76 percent per year/yr).
- Treatment emissions are relatively high and occur across the entire treated area.
- Treatment never reduces fire emissions by more than 40 percent. On average emissions were only reduced by 6 percent across five sites.
- In the absence of fire, treatment reduces sequestration.
- Retreatment will have to occur with accompanied emissions.
- A positive impact of treatment beyond the treated area is not guaranteed and is unlikely to ever be large enough to impact net greenhouse gas emissions.

Therefore, low fire probability is combined with high emissions and low sequestration in the absence of a fire. Also, there are relatively few emissions reductions in the event of fire.

Conclusions

Reducing emissions from fire could be an important contribution to reducing CO₂ emissions overall, yet the inherent reduction of carbon stocks in hazardous fuels treatments, combined with the low annual probability of fire on a given acre of land prevent the development of a workable carbon offset methodology for such treatments. It may be possible that specific treatments, removing a minimum amount of small diameter ladder fuels in certain forest ecosystems can yield an overall emission reduction. Furthermore, low-emissions technologies that are developed in the future may yield increased emission reductions. In the case of the standard fuels treatments for mixed conifer forests in Northern California and Southern Oregon, treatments led to increased net emissions over the 60 year modeling period. However, reducing the risk of fire is a critical activity for many other reasons, including enhancing forest

health, maintaining wildlife habitat, and reducing risk to life and property. Therefore, hazardous fuel treatments must continue and should be planned to minimize net emissions.

Benefits to California

In today's world where actions to curb atmospheric greenhouse gas concentrations are growing more urgent, an accurate accounting is important of all emission sources at national, regional and local levels. The work completed here allows a better understanding of the relative emissions that arise from hazardous fuel treatments and wildfires in low- to mid-elevation mixed conifer forests. While these results show that in the absence of wildfire, fuels treatments did not lead to net emission reductions, it is important for planners to understand relative greenhouse gas emissions to design treatments in a way that minimizes emissions while maximizing non-greenhouse gas benefits.

CHAPTER 1: Introduction

1.1 Background and overview

The West Coast Regional Carbon Sequestration Partnership (WESTCARB), led by the California Energy Commission, is one of seven US Department of Energy regional partnerships working to evaluate, validate and demonstrate ways to sequester carbon dioxide and reduce emissions of greenhouse gases linked to global warming. Terrestrial (forestry and land use) sequestration options being investigated include afforestation, improved management of hazardous fuels to reduce emissions from wildfires, biomass energy, and forest management. Shasta County, California and Lake County, Oregon were chosen for WESTCARB Phase II terrestrial sequestration pilot projects because of the diversity of land cover types present, opportunities to implement the most attractive terrestrial carbon activities identified in Phase I, and replication potential elsewhere in the WESTCARB region.

Fire was identified as the single largest source of emissions from forestland in California (Brown et al 2004). In California an estimated 1.83 MMTCO₂e are emitted per year due to fires on forests and rangelands (Pearson et al. 2009). For Oregon the value is 1.03 MMTCO₂e/yr, for Washington 0.18 MMTCO₂e/yr and for Arizona 0.47 MMTCO₂e/yr (Pearson et al. 2007 a, b, c). Policy mechanisms and/or incentives to decrease these emissions could therefore have profound effects on GHG emissions at the state and regional levels.

All carbon project activities work through interventions that lead to a decrease in emissions or an increase in removals (sequestration) relative to a reference or baseline case. In this situation, a carbon project developer would need to estimate the emissions from fire that are likely to occur within defined project boundaries without the implementation of project activities, and how the implementation of project activities would decrease these emissions. Therefore, the substantial challenge is to define the risk of fire and the emissions associated with that risk and to quantify how fuels treatments can diminish these emissions. A good deal of anecdotal evidence exists suggesting that fuels treatments in particular locations have appeared to reduce the intensity, spread, or emissions from fires, and/or slow the progress of fires enough to make suppression feasible. The challenge in this effort is to move from anecdotal evidence to a rigorous scientific methodology, quantifying in a transparent and replicable way the GHG benefits attributable to fuel treatments.

1.2 Project Objectives

The overall goal of WESTCARB Phase II is to validate and demonstrate the region's key carbon sequestration opportunities through pilot projects, methodology development, reporting, and market validation. WESTCARB will produce methodologies, plans, data, technical papers, and reports that facilitate informed decisions by policymakers, communities, and businesses on how to invest in carbon capture and storage technology development and deployment to achieve climate change mitigation objectives. This report focuses on one of those opportunities, creation of a methodology to track wildfire emissions reductions attributable to fuel treatments.

1.3 Report Organization

The report is organized in six key sections. In Section 2 the literature background is given together with the process undertaken: a straw-man method and the fire panel and work with fire experts. In Section 3 the analyses and results from work by fire experts are discussed. In Section 4 details and results are given from the parallel pilot studies that were undertaken under WESTCARB in Shasta County, California and Lake County, Oregon. In Section 5 the results from the consultancies and the field projects are integrated and conclusions made on the possibility of developing a methodology. In Section 6 literature that contrasts with the findings is reviewed in order to identify the sources for the different conclusions. Finally in Section 7 conclusions and recommendations are made addressing the implications of these findings and future opportunities.

CHAPTER 2: Literature Background, a Straw man and the Fire Panel

2.1 Current Status of Knowledge on Fire, Fuels Treatments and Greenhouse Gases

Calculating potential offsets from removal of hazardous fuel requires properly addressing all of the expected changes in carbon stocks and emissions that result from treatments. Past studies have addressed change in carbon stocks as a result of fire suppression policies, emissions from wildfire, and the effectiveness of treatments. More recently, a few researchers have addressed the impacts of hazardous fuels treatments on carbon stocks. However, these studies did not produce consistent results and did not always fully address all possible carbon stocks and sources of emissions. Much of this past research has considered emissions from fire as a given or has assumed that 100% of biomass removed in treatments will be utilized and none is emitted due to inefficiencies or decomposition. We explored existing research to identify which factors were considered when calculating the carbon balance of hazardous fuels treatments and to determine the most comprehensive methodology for such calculations.

2.1.1 Effects of fire suppression on carbon storage

Forest ecosystems in the U.S. provide a carbon sink that is estimated to be between 0.17 Pg C/yr and 0.37 Pg C/yr (Pacala et al. 2001). While some research has found that present day forests have lower live-tree carbon stocks than under historic active-fire conditions (North *et al.* 2009, Fellows and Golden 2008), numerous studies have found that 100 years of fire suppression has led to an increase in carbon stored in forests. Findings indicating an increase in sequestered carbon range in scope from the entire U.S. carbon sink (Houghton *et al.* 2000, Hurtt *et al.* 2002) to specific ecosystems such as oak savannah (Tilman *et al.* 2002) and Sierra mixed conifer forests (Bouldin 2009). With an increase in overall biomass, there is the potential for wildfires to release an increased amount of carbon to the atmosphere, especially as they become crown fires rather than simply surface fires, and it is important to have an understanding of the relationship between increased sequestration and increased wildfire emissions.

2.1.2 Pyrogenic CO₂ emissions

While wildfires where they occur may produce a high level of emissions, and may turn a forest from a carbon sink into a carbon source in the short-term, their impact over the long term is likely to be far less than anthropogenic emissions. A study of wildfires in the Metolius watershed in Oregon over two years found that emissions were equal to 2.5% of the statewide emissions of CO₂ from fossil fuel use and industrial processes during the same period (Meigs *et al.* 2009). Dore *et al.* (2008) found that after a stand-replacing fire, carbon losses may continue due to the slow recovery of gross primary production. However, Meigs *et al.* point out that most fires are not stand-replacing, and so it is important to account for the emissions from low to moderate severity fires. Campbell *et al.* (2007) found that over 60% of the emissions in a large wildfire in Oregon came from surface fuels, which would decompose over a period of 10 to 20

years in the absence of a fire, and would for the most part be emitted into the atmosphere anyhow.

Wiedinmyer and Neff (2007) address the variability of CO₂ emissions from fires across the U.S. that they say produce, on average, 4-6% of anthropogenic emissions. They state that wildfires have a near neutral effect on atmospheric CO₂ over the course of multiple decades when regrowth is allowed and factored into the equation. They also point out that fire presents one of the greatest risks to stored terrestrial carbon in the short term, and this risk introduces a high level of uncertainty in projecting forest carbon storage, particularly with changes in fire frequency. However, the effects of such changes are ecosystem-dependent. In looking at the case study of the Yellowstone fires, Kashian *et al.* (2006) found that with the long fire return intervals and relatively rapid regeneration that occurs in that ecosystem, landscape-level carbon storage is not significantly changed as a result of changes in fire frequency because these forests regenerate at such a rapid rate.

2.1.3 Effectiveness of fuels treatments

The basis for hazardous fuels treatments is that they reduce the intensity and extent of subsequent wildfires. It is reasonable to imagine that different fuels treatments yield different results in terms of reducing the severity and extent of wildfires. Agee and Skinner (2005) discuss a three-part objective for fuels treatments: reducing surface fuels, reducing ladder fuels, and reducing crown, and note that these goals can be accomplished using prescribed fire and thinning. However, they caution that not every forest is a high priority candidate for treatment. Lippke *et al.* (2007) found that treating the stand for a target basal area led to decreased wildfire hazard for 45 years, while removing all of the trees under 9 inches diameter at breast height (dbh) or over 12 inches dbh had little or no effect on wildfire intensity and extent. North *et al.* (2009) also found that removing overstory trees did not significantly improve fire resistance. Hurteau and North (2009) looked at eight types of treatments in Sierra Nevada mixed conifer forests and found that those that created a stand with lower tree density of primarily large, fire resistant pines were most successful at protecting the stand. Similarly, Lenart *et al.* (2009) note that after the Rodeo-Chediski fire in Arizona, those stands that had been thinned of smaller diameter trees sustained less damage than un-thinned stands.

The success of treatments also depends on the forest ecosystem. Pollet and Omi (2002) show that while fuels treatments are often successful in forests with short fire-return intervals, they are less cost-effective in stands with longer fire-return intervals, and placement of treatments should be balanced with the risk of loss from a fire in urban interface areas. Schoennagel *et al.* (2004) show that while fuel load has the greatest impact on fire behavior in some areas, climatic factors are more significant in other areas where thinning may not significantly impact wildfire behavior.

It is also important to note that different types of treatments will lead to different levels of biomass reduced and carbon emitted. Lippke *et al.* (2007) note that all treatments reduce carbon storage, while not all reduce wildfire severity. The treatments that Stephens and Maghaddas (2005) and Zald *et al.* (2008) found to be most successful at reducing the severity of fires incorporate understory thinning and prescribed burning to reduce surface fuels. In a prescribed

burn, the majority of the treated material is an immediate emission, although Narayan *et al*. (2007) found that prescribed fire can have reduced emissions when compared to wildfire, depending on the fire return interval. In the case of understory thinning, in many areas there are no mechanisms to use small diameter wood, and most or all of the biomass removed in such treatments will be emitted to the atmosphere as CO₂ in a relatively short time frame. North *et al*. (2007) suggest that historic forest conditions may be best adapted to resisting stand replacing fires, but they found that thinning alone did not return stands to these conditions; understory thinning combined with prescribed fire was the treatment that most closely resulted in forests that approximated 1865 conditions.

2.2 Conceptual Framework

The aim of this research was to produce a methodology that could be used by potential carbon projects to quantify their baseline emissions, project emissions with activities to reduce hazardous fuels, and estimate the associated project carbon. To that end, a general conceptual framework was developed under which a detailed conceptual model could be tested to determine the full impacts of hazardous fuels treatments on wildfire and greenhouse gas emissions. The basic question is-

What net impact do hazardous fuel treatment activities have on the total quantity of greenhouse gases emitted to the atmosphere?

The general conceptual framework includes the approach for estimating the emissions in the baseline case (without fuel treatment) and the approach for the project case (with fuel treatment) as follows:

The baseline case is estimated as:

The area that would have burned in the absence of project activities multiplied by the emissions that would be expected per unit area burned.

The project case is equal to:

The estimated emissions from removal of hazardous fuels less any carbon stored in long-term wood products or reduced emissions from bioenergy substitutions, plus emissions per unit area burned from any fires that occur on the project land through time after fuel treatment.

The detailed conceptual model includes the following factors:

1. **Annual Fire Risk**: The occurrence, spread, and intensity of forest wildfires are unpredictable and, for any specific area of forest, relatively rare. Given this nature of forest wildfires, the application to fuel treatments projects would need to examine the likelihood of fire occurring on any given acre across the project area in any given year. In this model, a performance standard function for fire is needed that is referred to here as an annual fire risk (or probability) distribution. This fire risk distribution would be applied in both with and without project scenarios.

- 2. **Emissions as a Result of Treatment**: Fuels treatments lead to reductions in carbon stocks in the treated stands as fuels are cut to the ground and/or removed. These fuels enter the atmosphere via one of 5 pathways
 - a. Decomposition over time of the treatment-produced dead material on the forest floor
 - b. Prescribed under burn with associated CO2 and non-CO2 greenhouse gas emissions
 - c. Piling and burning with associated CO₂ and non-CO₂ greenhouse gas emissions
 - d. Extraction for wood products with subsequent emissions due to milling inefficiency and product retirement (and burning/decomposition)
 - e. Extraction for the production of energy with associated emissions from combustion balanced to a given extent by offsetting the displaced fossil fuel emissions from energy production
- 3. Emissions as a Result of Fire: If a fire occurred in a forest stand, emissions will clearly differ depending on whether or not treatment has occurred and on climatic conditions. Given the complexity of fire behavior, invariably fire emissions must be modeled based on input data on stocks and stand composition.
- 4. **Forest Growth / Regrowth**: Forest growth must also be considered in both the project and baseline case. Fuels treatments may lead to either an increase or decrease in growth rates relative to the baseline:
 - a. Removing hazardous fuels will provide more growing space for the remaining trees, allowing them to grow at a faster rate, possibly removing additional carbon from the atmosphere.
 - b. Alternatively, removing hazardous fuels removes trees that in the baseline would have been sequestering carbon from the atmosphere thus leading to a net decrease in growth in the project case relative to the baseline.
- 5. **Retreatment:** As a result of forest growth, there will likely be a need to retreat forests periodically to maintain the benefits of reduced emissions from wildfire.
- 6. **Shadow Effect**: The baseline and project must also account for the "shadow effect" of fuel treatments—that is an area that is not treated, but, because of treatments there is a reduced risk of fires and/or reduced fire emissions as a result of treatment. This may be because the fire is more easily extinguished or because the fire will have decreased to the forest floor and will not immediately climb back into the canopy.

The impact of the project on gains and losses of carbon is summarized as follows:

- Gain from *decreased* intensity or spread of fire due to fuel treatment within the project and shadow areas (based on annual fire probability).
- Loss from biomass removed during treatment.

- Gain /Loss from substitution of fuels for energy generation.
- Gain from long term storage of wood products from removed biomass during fuels treatment.
- Loss from decomposition of additional dead wood stocks created through fuels treatment.
- Gain /Loss from growth differences between treated and untreated, and with and without fire.
- Loss from fires occurring in treated project case (based on annual fire probability).
- Loss from retreating forest stands through time.

A positive net result indicates increased carbon storage as a result of the treated project. A negative net result indicates a net loss in carbon storage and increased emissions as a result of the treated project.

2.3 Creation of a "straw man" methodology

Considering the complexity of the task and absence of any comparable effort to use as a starting point for the effort, the decision was made to create an initial simplified methodology that could be presented to a panel of fire experts and serve as the basis for discussions, critiques and progress forward:

Brown et al. 2006, Protocol for monitoring and estimating greenhouse gas benefits from hazardous fuels management in Western U.S. forests. Report for the West Coast Regional Carbon Sequestration Partnership Phase II.

Winrock took the approach of a 10-year moving window of fire probability based on data for northern California defining the risk of the project area burning in the baseline. The straw man methodology is included in Appendix A.

2.4 WESTCARB Fire Panel

Fire experts from the WESTCARB region were identified and invited to join a WESTCARB Fire Panel for GHG methodology development¹. Four meetings were held with various members of the Fire Panel participating.

The full Fire Panel was convened in October 2006, to begin the task of methodology development with Winrock's "straw man" methodology as a starting point. The workshop

¹ While the members of the fire panel were instrumental in discussing issues related to hazardous fuels treatments, fire risk, and methodology development, the panel did not reach a final consensus, and the ultimate findings of this report are the conclusions of the authors, rather than the full fire panel.

brought together fire scientists, carbon scientists and fuels management experts for discussion of approaches to quantifying baseline emissions from wildfires, estimating emission reduction/sequestration benefits of fuel reduction, and developing measuring, monitoring and verification protocols to qualify these projects for carbon reporting and/or markets. The desired outcome of the workshop was to identify areas of agreement and issues requiring further research, as well as to clarify roles and potential contributions of Fire Panel members in ongoing protocol development. Fire Panel members were reminded that the desired outcome of the WESTCARB fire methodology task was a methodology that is cost-effective, practical and transparent for landowners/land managers to use, conservative in its GHG estimates, and has sufficient scientific credibility ultimately to qualify these activities for carbon market recognition.

Workshop participants included:

- California Department of Forestry and Fire Protection: Elsa Hucks, Doug Wickizer
- California Air Resources Board: Neva Sotolongo
- Lake County Resources Initiative: Bill Duke
- Oregon Department of Forestry: Jim Cathcart
- Oregon State University: Olga Krankina
- Sylvan Acres LLC: Brent Sohngen
- University of California at Berkeley Center for Fire Research and Outreach: Max Moritz
- USDA Forest Service Pacific Northwest Research Station Pacific Wildland Fire Sciences Laboratory: Sam Sandberg
- USDA Forest Service Pacific Southwest Research Station Redding Silviculture Laboratory: Bob Powers
- USDA Forest Service Pacific Southwest Research Station Sierra Nevada Research Center: Mark Nechodom
- USDI National Park Service Whiskeytown NRA: Tim Bradley
- W.M. Beaty and Associates: Bob Rynearson
- Western Shasta Resource Conservation District: Leslie Bryan, Jack Bramhall
- Winrock International: Sandra Brown, Tim Pearson, Nancy Harris, Silvia Petrova, Nick Martin, John Kadyszewski

An expert subgroup met in May 2007 to discuss, in a smaller group setting, key methodological issues that had been identified in the full Fire Panel meeting as needing further discussion or alternative approaches. In preparation for this meeting, Winrock asked Panel members Sam Sandberg of the PNW Research Station, and Scott Stephens and Max Moritz of the University of California at Berkeley, to work on developing alternative baseline methodologies for estimating emissions and area burned, respectively. Progress and results to date on alternative approaches were presented, followed by open discussion and consideration of next steps.

Meeting participants included:

- University of California at Berkeley Center for Fire Research and Outreach: Max Moritz, Eric Waller, Scott Stephens
- USDA Forest Service Pacific Northwest Research Station Pacific Wildland Fire Sciences Laboratory: Sam Sandberg (Emeritus Physical Scientist)
- USDA Forest Service Pacific Southwest Research Station Sierra Nevada Research Center: Mark Nechodom
- TSS Consultants: David Ganz
- Spatial Informatics Group: David Saah
- Winrock International: Sandra Brown, Tim Pearson, Nancy Harris, Silvia Petrova, Nick Martin

The subgroup met again in March 2008 to review the current status of the various separate efforts, determine if and how these efforts could be unified, and identify gaps that needed to be addressed. Participants at this meeting included:

- University of California at Berkeley Center for Fire Research and Outreach: Max Moritz
- USDA Forest Service Pacific Northwest Research Station Pacific Wildland Fire Sciences Laboratory: Sam Sandberg (Emeritus Physical Scientist)
- USDA Forest Service Pacific Southwest Research Station Sierra Nevada Research Center: Mark Nechodom
- TSS Consultants: David Ganz
- Spatial Informatics Group: David Saah
- Oregon Department of Forestry: Jim Cathcart
- Oregon State University: Olga Krankina
- Winrock International: Sandra Brown, Tim Pearson, Nancy Harris, Nick Martin, Katie Goslee

A final meeting took place in April 2010, when the researchers still actively involved met to determine final commonalities in their respective findings and discuss the overall potential for reducing greenhouse gas emissions through hazardous fuels reductions. Participants at this meeting included:

- University of California at Berkeley Center for Fire Research and Outreach: Max Moritz
- Spatial Informatics Group: David Saah
- Oregon Department of Forestry: Jim Cathcart
- Winrock International: Sandra Brown, Tim Pearson, Katie Goslee

CHAPTER 3: Consultations with fire experts and additional fire analyses

After the full WESTCARB Fire Panel workshop in October 2006, it was determined that expert fire modelers would be required to create a credible fire emissions reduction methodology. Two teams were contracted: Dr. Sam Sandberg, Emeritus Physical Scientist representing the USDA Forest Service - Pacific Northwest Research Station - Pacific Wildland Fire Sciences Laboratory, and Drs. Max Moritz, Scott Stephens and Eric Waller of the University of California at Berkeley - Center for Fire Research and Outreach. Two existing WESTCARB partners also conducted complimentary fire analyses – Oregon State University and the Oregon Department of Forestry.

3.1 Fire risk and firesheds

The UC Berkeley team focused on developing baseline fire risk (probability of an area being burned in a given year) for Shasta County, California, where fuel treatments were implemented in the WESTCARB terrestrial pilot locations.

Following the spring 2008 fire panel meeting, the work of the Center for Fire Research and Outreach was extended, and a consultancy with Dr. David Saah of the Spatial Informatics Group was added to incorporate the concept of firesheds and their relevance to fuels treatments.

The UC Berkeley team focused on developing alternate approaches to quantify baseline fire risk (i.e. probability of an area being burned in a given year) across the regions of northern California where WESTCARB fuel reduction pilot activities are being monitored. The group reached final conclusions that reinforced the findings of the initial Winrock work (in the straw man methodology) that modeled fire return intervals were between 120 and 300 years for mixed conifer forest types in Shasta County giving annual fire probabilities of less than 0.8% (0.008) (Figure 1).

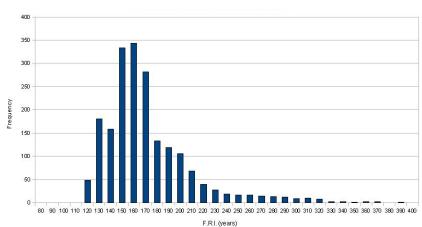
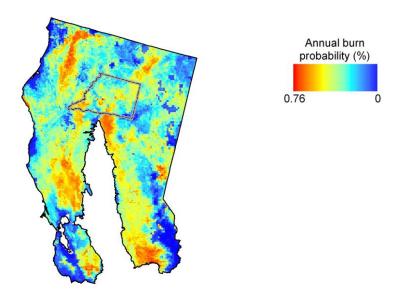


Figure 1: Histograms of Fire Return Intervals for Sierra Mixed Conifer.

Fire return intervals are calculated based on transformation of relative fire probabilities and historical burning rates for Shasta County over 2001-2007 14

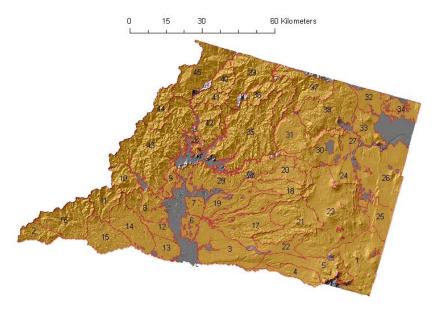
The Berkeley team produced a map showing how this value varies across the northern California landscape and across vegetation types (Figure 2).

Figure 2: Annual Burn Probability as Calculated by the UC Berkeley Fire Team (led by Max Moritz)



Within Shasta County, firesheds were delineated based on five main factors: the "fire behavior triangle" (fuels, weather and topography), barriers to fire spread (both natural and anthropogenic), potential fire behavior (under a "near-worst case" weather scenario), fire occurrence probability patterns, and fire history (Figure 3). For each fireshed a full set of attributes were defined (Table 1).

Figure 3: Firesheds Delineated for Shasta County, California.



Areas not enclosed by a fireshed are non-wildland/non-burnable, i.e. water, urban, agricultural, or barren (Saah *et al.* 2010).

Table 1: Summary of Fireshed Attributes for Shasta County, California.

NLCD indicates the land cover type code from the National Land Cover Database, 2001 (42 is evergreen forest, 43 is mixed forest, 52 is shrub, 71 is grassland/herbaceous). Area indicates the total number of acres in the fireshed. Fire probability values range between 0 and 1 and listed wind speed values are those expected under near-worst case scenarios. Surface flame length is listed in meters; surface fire line intensity is kW/m. Low, medium and high crown fire activities are classified as 1, 2, and 3 respectively.

Fireshed	NLCD Cover Type	Area (Acres)	Fire Probability	Fire Probability Standard Deviation	Windspeed (mph)	Topographic Roughness Index	Surface Flame Length	Surface Fire Line Intensity	Crown Fire Activity Class
1	42	85,157	0.261	0.054	23.53	1.019	27.88	42,526	3
2	42	24,859	0.389	0.061	21.9	1.081	20.95	37,143	1
3	71	73,845	0.461	0.050	24.25	1.006	7.89	9,219	1
4	42	25,997	0.447	0.103	22.8	1.015	37.1	58,395	3
5	42	56,444	0.339	0.140	23.65	1.029	30.45	47,855	3
6	71	14,817	0.392	0.018	23.86	0.999	3.66	3,995	1
7	71	13,811	0.433	0.014	23.85	1	2.84	2,494	1
8 9	52	27,656	0.551	0.045	24.02	1.021	7.59	10,514	1
	43	21,696	0.538	0.058	23.76	1.026	9.25	12,346	1
10	42	25,386	0.454	0.065	23.36	1.08	22.89	39,623	3
11	42	31,825	0.409	0.061	23.63	1.086	21.48	37,845	1
12	52	29,314	0.49	0.046	23.93	1.031	11.72	16,694	1
13	71 50	21,114	0.427	0.024	24.28	1.002	5.51	5,939	1
14	52	53,956	0.464	0.041	23.57	1.013	7.01	9,993	1
15	71	45,640	0.478	0.030	23.66	1.025	4.16	6,489	1
16	52	62,906	0.45	0.056	23.22	1.084	12.12	22,309	1
17	52	58,341	0.49	0.040	23.51	1.015	11.02	13,856	1
18	42	68,791	0.473	0.071	23.73	1.022	23.53	37,999	3
19	71	48,316	0.466	0.055	24.02	1.012	6.01	6,777	1
20	52	27,252	0.498	0.077	23.32	1.02	16.49	22,853	1
21	42	72,889	0.456	0.073	23.22	1.029	39.64	65,216	3
22	42	23,030	0.478	0.032	23.76	1.005	38.32	59,289	3
23	42	159,183	0.343	0.051	23.32	1.017	38.94	63,243	3
24	42	27,912	0.378	0.031	22.3	1.016	21.14	28,548	3
25	52	31,802	0.353	0.038	22.55	1.009	8.9	8,312	2
26	42	105,654	0.39	0.029	22.84	1.008	7	6,056	2
27	42	6,335	0.4	0.014	22.64	1.004	2.13	1,335	1
28	52 42	9,045	0.579 0.537	0.016	24.15	1.058	5.5 6.34	6,261	1
29 30	42 42	70,176 47,571	0.395	0.044 0.044	24.01 23.41	1.037 1.016		7,902	1
							11.89	13,756	2
31	42	53,530	0.472	0.049	23.22	1.036	20.87	33,088	1
32	42	25,018	0.425	0.007	22.65	1.001	14.86	18,262	2
33	42	31,906	0.418	0.015	23.63	1.021	9.36	11,660	1 2
34 35	42 42	25,027	0.409 0.5	0.014	22.37	1.003	4.38	3,221	
		133,539		0.030	23.88	1.106	14.8	21,026	1
36	42	45,897	0.48	0.050	24.06	1.099	30.32	46,920	3
37	42	53,928	0.405	0.084	22.59	1.081	25.48	36,514	3
38	42	83,237	0.401	0.054	23.76	1.041	31.85	50,594	3
39	42	60,599	0.505	0.043	22.88	1.108	24.31	36,169	3
40	42	20,114	0.534	0.028	23.32	1.108	20.82	31,915	1
41	42	29,433	0.521	0.036	23.25	1.123	14.88	20,581	1
42	42	37,955	0.575	0.039	24.12	1.093	9.7	12,673	1
43	42	163,176	0.506	0.051	23.3	1.101	12.79	20,239	1
44	42	29,424	0.449	0.061	25.12	1.096	34.54	58,901	3
45	42	67,736	0.414	0.102	22.79	1.073	22.68	30,693	3

The final report of the UC Berkeley team is included in Appendix B.

3.2 Fire Fuelbeds and Baseline Emissions

Dr. Sam Sandberg was tasked with developing estimates of emissions to be paired with the baseline rate of fire.

Sam Sandberg used the USFS fire model - Fuel Characteristic Classification System (FCCS). He proposed a process that could be used on a specific land ownership to estimate future carbon emissions for managed and unmanaged (i.e. baseline) scenarios: 1) predict into the future what harvest and fuel treatment strategies would be applied to a management unit; 2) customize fuelbeds to represent each of the future time periods and management options; 3) calculate the probability of wildfire on each fuelbed before and after treatment based on adjustments to the baseline algorithm using fire potentials; 4) calculate the carbon release from prescribed fire treatments and expected wildfire area. The adjusted annual fuel risk by different fuelbeds in the Shasta County region is shown in Figure 4 and the average emission from a fire in each fuelbed type by different moisture conditions in Figure 5. The final report of Sam Sandberg can be found in Appendix C.

Figure 4: Historic Annual Fire Risk for FCCS Fuelbeds in Ecosystem Province M261 (Sierran Steppe – Mixed Forest – Coniferous Forest – Alpine Meadow).



The individual fire risk is assumed to be the same for any Project Area (including Shasta County) in the Province.

Red fir forest Douglas-fir - Sugar pine - Tanoak forest Subalpine fir - Engelmann spruce - Douglas-fir - Lodgepole pine Tanoak - California bay - Madrone forest ■ Fuel Moisture = 30% Ponderosa pine - Jeffrey pine forest ☐ Fuel Moisture = 12% Pacific ponderosa pine forest Douglas-fir - ponderosa pine forest Fuel Moisture = 8% Douglas-fir - Madrone / Tanoak forest Fuelbed name Jeffrey pine - Ponderosa pine - Douglas-fir - Black oak forest Lodgepole pine forest Pacific ponderosa pine - Douglas-fir forest Western juniper / Huckleberry oak forest Chamise chaparral shrubland Ponderosa pine savanna Live oak - Blue oak woodland Western juniper / Sagebrush savanna Scrub oak - Chaparral shrubland Black oak woodland Wheatgrass - Cheatgrass grassland 0 20 40 10 30 50 60 (tons/acre)

Figure 5: Carbon Emissions (tons/acre) for FCCS Fuelbeds in Oregon/California at Three 1000-hr Moisture Content Profiles.

The "8%" moisture profile represents an average wildfire; 12% and 30% represents a range in emissions expected from prescribed fire in each fuelbed.

3.3 Impact of Fuel Treatment on Stand Growth

Oregon State University completed literature and analyses of data on rates of decomposition of woody debris. OSU also examined the impact of fuel treatments on stand growth and carbon sequestration using the STANDCARB model. The reference data for model calibration was obtained from the US Forest Service – Forest Inventory and Analysis database, and model settings were adjusted to represent realistically the regional patterns (in Southern Oregon) of live tree biomass accumulation with age of forest stands for one forest type (Ponderosa pine). The team developed a set of thinning and fire scenarios to be simulated. Preliminary model outputs suggest that after 200 years of application of aggressive thinning (e.g., 35% removal every 15 years or 50% removal every 25 years) carbon stores in live biomass and total biomass declined by about 20 and 30 t C/ha respectively, with smaller losses for moderate thinning regimes. This loss represents 15-20% of the baseline scenario, though use of harvested wood could reduce this loss. On average, over 200 years of applying these thinning schedules the losses of live biomass ranged from 4 to 14 t C/ha compared to a no-thin scenario. The effect of

thinning on the average C store in forest fuels was small; moderate thinning had virtually no effect; more aggressive thinning reduced forest fuel load on average by 0.5-1.9 t C/ha or 1-4% of the forest fuel load in baseline scenario. For thinning to be effective as a measure to reduce carbon emissions from fires, the emission reduction has to be greater than the estimated losses of biomass caused by thinning. OSU's reports are included in Appendix D.

3.4 Case Study Simulation of Fuel Treatments and Wildfire Emissions – Lake County, Oregon

The Oregon Department of Forestry conducted separate research that addressed the question does fuels treatments result in an overall carbon benefit from reduced wildfire emissions through a case study simulation analysis of fuel treatments and wildfire emissions (Cathcart et al, In Press). The case study addressed the 169,200 acre Drews Creek watershed in Lake County, Oregon that is comprised of agricultural lands, juniper woodland, dry ponderosa pine forests, and mixed conifer forests. Within the watershed, 9,500 acres have burned over the last 50 years. The researchers modeled the effects of the anticipated large "problem fire," to be avoided through the Fremont-Winema national Forest's fuel treatment planning effort. The problem fire is a blow-up event under sever fuel moisture and weather conditions that burns 11,000 acres over an 8-hour afternoon burn period. Fuels treatments were modeled by thinning from below and under-burning a total of 12,825 acres, 9.1% of the watershed's forestland. Using ArcFuels software, wildfires under extreme fuel moisture and weather conditions were simulated over the 8 hour burn period with 10,000 random ignitions for both the treated (with project) and untreated (baseline) watershed. Conditional probabilities, both for wildfire reaching a given stand and for its intensity once it reached the stand, were calculated for the treated and untreated landscapes. The effect of the fuel treatments on wildfire risk were based on the treatments lowering both the conditional probability of wildfire reaching a stand, and the probability of higher severity fires once fire reached treated stands. The conditional burn probabilities averaged 2.2% (0.0022) for the untreated watershed and 1.7% (0.0017) for the treated watershed; the effect of the fuel treatments only reducing the average conditional burn probability by 0.05% (0.0004). As seen in the other studies, the predominate simulation for a given stand was that no wildfire occurred – averaging 97.9% of the time for the treated watershed.

The study design explicitly simulated the shadow effect of the treatments by calculating the avoided wildfire emissions in untreated stands as a result of the treatments. The area of the shadow effect was assumed to be the watershed boundary. The results showed that the likelihood of fire reaching untreated stands decreases with treatment. Carbon stocks lost in thinning and under-burning were estimated to be -271,333 tons of carbon (-21.2 tons per treated acre). In comparison, only an expected 3,700 tons (0.21 tons per acre) of avoided carbon loss from wildfire accrued to the project as a result of the treatment's effect of reducing both the likelihood and intensity of wildfire. The avoided emissions from the treatment shadow effect was an additional 3,087 tons of expected avoided carbon loss (0.025 tons per untreated acre) as a result of the treatment's effect of reducing the likelihood of wildfire in untreated areas. The total avoided emissions benefit from treatment was 6,787 tons of expected carbon loss avoided (0.048).

tons per forested acre). This low expected avoided emission is again due to the infrequent probabilistic nature of wildfire. The net offset from avoiding the chance of a problem fire from a given ignition within the watershed under severe fuel moisture and weather was -264,546 tons (-1.9 tons per forested acre). Given these emissions, and the one-time investment of fuels treatments to avoid a "problem fire," if there were five ignitions per year under severe weather conditions (dry conditions with relatively high wind speeds); the break even shelf life (the time the treatment's carbon losses are recouped from avoided wildfire emissions spanning several years following treatment) is nine years.

CHAPTER 4: Field Data and Modeled Fuels Treatment Projects

4.1 The Purpose of Measurement and Modeling Activities

To gather real-world data for an assessment of fuel treatment project methodologies, pre- and post-fuel treatment carbon stock measurements were conducted by Winrock International and its WESTCARB partners on several treated areas. The purpose of the measurements was to provide ground data from real treatments as input into a model of a hypothetical greenhouse gas emission reduction projects. Measurements identified the carbon stocks before and after treatment, the direct impacts of fuel treatments on carbon stocks in different carbon pools (e.g. increases in dead wood, decreases in dense growth), and the fuel removed from the forest for biomass energy or wood products during treatment. Two hazardous fuel treatment projects were identified in Lake County, Oregon and three in Shasta County, California.

These measurements were used to determine the carbon stocks before and after treatment and before and after a potential wildfire, for each project area. Growth modeling was conducted with the Forest Vegetation Simulator for both with and without treatment stands. Emissions from a potential fire were modeled in both with- and without-fuels treatment scenarios using both the Fuel Characteristic Classification System (FCCS) and the Forest Vegetation Simulator fire and Fuels Extension (FVS-FFE). FVS was also used to project growth on burned stands, incorporating the impacts of fire on the future stand.

More information on the fuels treatment and results can be found in the full pilot study reports:

Goslee, K., T. Pearson, S. Grimland, S. Petrova, and S. Brown. 2010. *Final Report on WESTCARB Fuels Management Pilot Activities in Shasta County, California*. California Energy Commission, PIER. CEC-500-XXXX-XXX.

Goslee, K., T. Pearson, S. Grimland, S. Petrova, and S. Brown. 2010. *Final Report on WESTCARB Fuels Management Pilot Activities in Lake County, Oregon*. California Energy Commission, PIER. CEC-500-XXXX-XXX.

4.2 Summary of Results

The initial stocks of forests in the five sites were between 51 and 82 t C/ac dropping to between 34 and 72 t C/ac after treatment with an average decrease of 12 t C/ac (Table 2). Decreases in stocks due to wildfire were estimated at between 8 and 12 t C/ac in the absence of treatment and between 7 and 13 t C/ac if a treatment had occurred.

Table 2: Carbon Stocks (in t C/ac) for Each of the Five Treatment Locations Before and After Treatment and Modeled with and Without an Immediate Wildfire.

		Pre-Trea	tment	Post-Treatment			
		No fire	Wildfire	No fire	Wildfire		
Oregon	Bull	82	70	72	59		
	Collins	55	47	34	25		
California	Davis	51	41	48	39		
	НН	64	53	55	45		
	Berry	70	58	51	44		

On a percentage basis (Table 3) treatment led to an average of 19% reduction of stock (range 6-38%). Wildfires led to a reduction in stocks of 17% on average where no treatment had occurred or 19% with fuel treatment.

Table 3: The Percentage Change in Stocks at Each of the Five Treatment Locations as a Result of Treatment and in Response to a Wildfire with and Without a Treatment.

		Reduction due	Reduction due to fir			
		to treatment	No Treatment	With Treatment		
Oregon	Bull	12%	15%	18%		
	Collins	38%	15%	26%		
California	Davis	6%	20%	19%		
	НН	14%	18%	18%		
	Berry	27%	17%	14%		

In all cases treatment led to a decrease in carbon removals (sequestration) in the absence of wildfire (Table 4). In every case the situation was reversed where a wildfire occurred.

Fuel treatment reduced wildfire emissions by an average of 6%. However, the ratio varied from a decrease of 38% to an increase of 16% (Table 4). This variation is likely related largely to the intensity of treatment and the size composition of the stand prior to treatment.

Table 4: The Impact of Fuel Treatment and Wildfire on Carbon Removals Through Forest Growth (over 60 years), Emissions Resulting From Wildfire and Net Emissions Considering All Input Factors, Handling of Fuels and Risk of Fire for Each of the Five Locations. A Negative Indicates a Net Emission, a Positive Indicates a Net Removal.

		Growth 1				Fire Emissions		NET EMISSIONS	
	Treatment	No	Yes	No	Yes	No	Yes		
	Wildfire	No	No	Yes	Yes	Yes	Yes	Short Term	Long Term
		t CO ₂ /ac							
Oregon	Bull	14	29	106	72	-43	-47	-47	-37
	Collins	92	62	-36	-26	-29	-33	-108	-113
California	Davis	212	184	55	69	-37	-34	-39	-60
	НН	205	180	57	94	-40	-35	-84	-91
	Berry	172	129	6	99	-43	-26	-83	-116

Short term = 10 years; Long term = 60 years

The net emissions incorporated regrowth following fire and following treatment plus the risk of fire occurring. Risk of fire was derived from the work of UC Berkeley and was equal to 0.64% for the sites in Shasta County and 0.60% for the sites in Lake County. Using the full accounting methodology, a proportion of biomass extracted as timber is accounted as a permanent removal. However, for biomass energy the extracted biomass serves to displace fossil fuels burned for power generation. In California, new power is generated by burning natural gas and natural gas produces fewer greenhouse gas emissions per megawatt hour of power production than burning biomass. Thus, all biomass extracted during treatment for energy production results in a net emission (albeit lower than if the stocks had been burned on site).

Many interpret the fact that biomass is replaceable (in the way that fossil fuels are not) to mean that all biomass burned has no net impact on the atmosphere. But burning biomass does increase greenhouse gases resident in the atmosphere. Burning biomass might prevent emissions from fossil fuels, but this is by no means permanent. In this debate about use of biomass for power production, it is critical to focus on the atmosphere, i.e. does the project cause an increase or decrease in the concentration of carbon dioxide in the atmosphere? In the case of burning biomass rather than natural gas, the net result is an increase in CO₂ in the atmosphere because natural gas burns more cleanly than biomass. If coal were displaced instead of natural gas the savings would be greater while if the displacement is of electricity generated by nuclear power, solar, wind or hydro power then the result is an emission with no net saving.

If the stand is not treated the fuels are available in the forest to be emitted to the atmosphere through wildfires, and as shown above in the CA and OR region this risk is very low. However, this should not be considered under the biomass energy calculations. If it is then, the baseline fire emissions would be counted twice. The baseline fire risk multiplied by the stock gives the baseline emission from wildfires, which is the emission from fuels in the absence of fuel treatment.

Considering the disposition of biomass and the risk of fire, the analyses at the five pilot sites showed net emissions of between 47 and 108 t CO₂e/ac within ten years and between 37 and 116 t CO₂e/ac after 60 years have passed (Table 4).

This analysis integrates a risk of fire based on the measured fire return interval. Thus if a fire actually occurs then the result would be a net removal but in reality the balance of probabilities indicates that a fire will not occur and in this case the net emission would be yet higher.

This analysis integrates a risk of fire based on the measured fire return interval. Thus if a fire actually occurs then the treatments reduce emissions sufficiently to result in a net removal. However, it is far more likely that a fire will not occur on the landscape, in which case, the net emission would be yet higher due to the removal of carbon stocks in the treatment.

More details are found in the two pilot study reports.

CHAPTER 5: Integration and Offset Methodology Conclusions

The results of the analyses and measurements are strongly conclusive:

- The annual fire risk does not exceed 0.76% in any of the forest types examined in parts of CA and OR.
- Fuels treatment leads to reductions in stocks of 10 to 40% with corresponding emissions.
- Fuels treatments must be conducted across a wide area due to the unpredictability of fire occurrence.
- Fuels treatments must be repeated to maintain efficacy.
- Fuels treatments undoubtedly make a fire more easy to control and thus save lives, however, the measured treatments only led to a 6% reductions in emissions from a wildfire occurring immediately after treatment in the five sites examined.

The net result is an increase in emissions, as a result of treatments, of between 30 and 120 t CO₂-e/ac. In addition, this value cannot be decreased through using fuels for biomass energy for these project areas (at least given current extraction technologies and equipment fuel efficiencies).

Ultimately, for fuels reduction to be a credible offsets project, it would be necessary to be able predict exactly where fires are going to occur and implement well designed fuels treatments in those locations. In reality this is of course impossible given current modeling capabilities.

5.1 Revisiting the Conceptual Framework

- 1. **Annual Fire Risk**: Multiple studies under this task identified annual fire risks of less than 1%. Based on ten-year moving average, Winrock estimated annual burn risks of 0.12% for private lands and 0.33% for public lands in Northern California. The more detailed analysis of the UC Berkeley team determined a mean annual fire probability of 0.64% for mixed conifer forests in Shasta County, California and 0.60% for mixed conifer forests in Lake Country, Oregon. In no case were probabilities higher than 0.76%/year. Thus there is a less than 1 in 130 chance of a fire at any site in any given year and for some sites it is 1 in 300 or more.
- 2. **Emissions as a Result of Treatment**: Across the five measurement sites in California and Oregon hazardous fuel treatment led to reductions in stocks of between 6 and 38% (average 19%).

Where timber was extracted, between 25.5% (in CA) and 30.9% (in OR) of the extracted biomass can be considered permanently sequestered in wood products. The remaining ~70% is emitted to the atmosphere over time.

Where biomass is extracted for power generation there is a net emission of 1.334 t CO₂/ton of biomass burned where the displaced fossil fuel is natural gas (as in California) or as low as 0.833 t CO₂/ton of biomass where the displaced fossil fuel is coal.

Any treated biomass not extracted from the forest will be emitted to the atmosphere – the only difference being if fire is used (underburn or pile) then non-CO₂ gases will also be emitted. Methane has an atmospheric impact 23 times that of carbon dioxide and nitrous oxide has an impact that is 310 times that of carbon dioxide.

- 3. **Emissions as a Result of Fire**: Across the five measurement sites in California and Oregon fuel treatment led to changes in emissions from subsequent wildfires of between a 16% increase² in emissions and a 38% reduction in emissions. On average emissions were reduced by 6%.
- 4. **Forest Growth/Regrowth**: Across the five measurements sites growth modeling showed a higher rate of sequestration after 60 years in stands with no treatment compared to treated stands in the absence of wildfire (on average 17% lower sequestration). Where a wildfire occurs the relationship is reversed with the total sequestration higher where treatment had occurred (on average 63% higher sequestration).
- 5. **Retreatment**: Hazardous fuels regrow rapidly. No analysis was conducted on this component of the conceptual framework, however, it is considered likely that retreatment will be needed every 10 to 20 years. Over a twenty year period even assuming the highest fire risk there is only a 15% chance that a fire will have occurred.
- 6. **Shadow Effect**: Analysis of the shadow effect by the UC Berkeley/SIG team revealed that no simple relationship or assumption can be derived. The size of the shadow effect will depend on the level of hazardous fuels in surrounding forests, the climatic conditions, the access to the site and the relative presence of fire fighters and firefighting equipment. The shadow effect may be zero where no immediate effort is possible at extinguishing the fires and where the fuel and climatic conditions are favorable for rapid reclimbing into the canopy. Dr Sam Sandberg estimated that the shadow area would not exceed five times the treated area. The Oregon Department of Forestry simulation assumed that the boundary of the shadow effect coincided with the watershed boundary, and modeled emission avoidance occurring in the shadow area explicitly. In this instance, accounting for the shadow effect doubled the calculated gross emission avoidance benefits from a single random emission, but that was still much lower than the initial carbon cost of the treatments themselves.

Consolidating across the conceptual framework the following conclusions can be reached:

- Fire risk is very low
- Treatment emissions are relatively high and are incurred across the entire treated area

² Increases in emissions following fuels treatments were primarily the result of an increase in 1- and 10-hour fuels.

- Treatment never reduces fire emissions by more than 40% and on average across five sites only reduced emissions by 6%
- In the absence of fire, treatment reduces sequestration
- Retreatment will have to occur with accompanied emissions
- A positive impact of treatment beyond the treated area is not guaranteed and is unlikely to ever be large enough to impact net greenhouse gas emissions

So low fire probability is paired with high emissions and low sequestration in the absence of a fire and relatively few emissions reductions in the event of fire.

5.2 Supporting Literature

Related research on the Mendocino National Forest in Shasta County (Pearson *et al.* 2010) showed similar results. This study looked at the effects on wildfire emissions of fuels treatments done under a Forest Service Stewardship Contract. In this case, the treatments did not reduce the risk of fire, nor did they decrease emissions from fire, and the reduction of carbon stocks lead to a large net gain in overall emissions.

These conclusions are supported by a recent study that addressed the uncertain probability of fire (Mitchell *et al.*, 2009) and the long-term carbon impacts of fire on three ecosystems in the Pacific Northwest: east Cascades ponderosa pine forests, west Cascades western hemlock-Douglas-fir forests, and Coast Range western hemlock-Sitka spruce forests. The study found that hazardous fuel reduction projects more often than not reduce more carbon than they allow the stand to store with an increased resistance to wildfire. One of the reasons for this is that much of the carbon that is stored in the forest is not immediately consumed even in high-severity fires. The authors of this study recommend that while fuel reduction projects may be the best management option in high risk forests near urban areas, other forests may be best used for their ability to sequester carbon, and not treated for fuel reduction.

CHAPTER 6: Contrasting Literature

Given the conclusion of the work here that there is currently no opportunity for fuels reduction as a greenhouse gas emission offset category, it is perhaps surprising that many studies have come out demonstrating a positive greenhouse gas impact of fuels treatments. It should be noted that the majority of these studies had different purposes to our own so it is not surprising that inconsistencies exist. However, for full atmospheric accounting purposes, the conclusions in these studies have omitted certain aspects of carbon accounting that are essential. Here the authors take each study showing a positive impact and discuss where these omissions occurred:

Finkral and Evans (2008)

The effects of a thinning treatment on carbon stocks in a northern Arizona ponderosa pine forest.

Publication Conclusion: The authors state that the thinning treatment resulted in net emissions of 3,114 kg C/ha (4.8 t CO₂-e/ac), though if the wood removed had been used in longer lasting products, the net carbon storage (relative to without thinning) would have been around 3,351 kg C/ha (1.9 t C/ac). So that thinning for treatment of fuels with storage in long term products results in a net emission reduction of 6.97 t CO₂-e/ac.

Forest type: Northern Arizona ponderosa pine

Treatments: pre-settlement restoration

Stocks: pre-treatment: 48.88 tons/ha; post-treatment: 36.42 tons/ha

Fire risk: 2.8%

Wildfire emissions: wildfire was modeled using FVS, and emissions were estimated at about 20% of carbon stocks for both treated and untreated

Emissions from prescribed fire: N/A

Emissions from treatment: 0.091 tons/ha emitted from equipment use for harvest and transport.

Utilization: firewood, because markets for longer-lived products were not available

Reassessment Conclusions: The authors assumed that a fire takes place and the emissions from fire are a given in their calculations. Accounting for the potential for fire (multiplying emissions by the 2.8% risk of fire), if wood is used as firewood, the treatment emissions are 5,457 kg C/ha (8.1 t CO₂-e/ac). In addition, in accounting for the net storage or release of carbon if the wood is used for longer lasting products, the authors did not incorporate mill inefficiencies. Incorporating both inefficiencies and risk of fire for longer lasting products, net carbon emission due to fuel treatment is 1.8 t CO₂-e/ac (1,131 kg C/ha) as opposed to the net emission reduction as a result of fuel treatment calculated in the paper of 7.0 t CO₂-e/ac (a difference of 8.8 t CO₂-e/ac). This value does not account for the rate of turnover/retirement of the wood products –

using USFS defaults for the Rocky Mountain region 63.3% of the extracted material is emitted to the atmosphere within 100 years.

North, Hurteau, and Innes (2009)

Fire suppression and fuels treatment effects on mixed-conifer carbon stocks and emissions.

Publication Conclusion: The authors conclude that forests with large trees, approximating 1865 active fire stand conditions, act as fire-resistant carbon sinks, storing high levels of carbon, and that such stands could be achieved with minimal reductions in existing carbon pools.

Forest types: Sierra Nevada mixed conifer

Treatments: 6 types: no thinning, understory thinning, and overstory thinning, each with and without prescribed burning

Stocks: Range of 66 Mg C/ha in most intensive treatment, overstory thin and burn, to 250 Mg C/ha in control. The percent change from pretreatment mean was as follows: burn only, -6.8%; understory thin, -28%; understory thin and burn, -34%; overstory thin, -56%, overstory thin and burn, -65%.

Fire risk: does not address risk of wildfire

Wildfire emissions: does not address emissions from wildfire

Emissions from treatment: Emissions sources included prescribed burn, equipment releases, trucking to the mill, and milling waste, with milling waste being the highest emission and prescribed burning being the second highest. (Only equipment and trucking are not accounted for in stocks above.) Carbon storage in long-lived wood products was not addressed.

Reassessment Conclusions: The study did not model fire, only discussed basic fire principles, such as fuel loads and crowning index and how these were affected by treatments. Thinning increased crowning index and prescribed fire reduced loading in most fuel classes. Without knowing the potential wildfire emissions after each treatment type, it is difficult to assess the actual carbon balance of the treatments using our framework.

USDA Forest Service (2009)

Biomass to Energy: Forest Management for Wildfire Reduction, Energy Production, and Other Benefits.

Publication Conclusion: The authors conclude that the treatments provide a net benefit for total energy consumption and reduced emissions.

Forest types: Sierra Nevada mixed conifer

Treatments: 13 prescriptions, including clear cutting, pre-commercial thinning, commercial thinning, salvage logging, select harvest, and restrictive thinning, with use of underburning

Stocks: N/A (compared treatment emissions and risk of fire, rather than calculating stocks)

Fire risk: chose discrete ignition points at locations across the landscape

Wildfire emissions: reference case: 17,000,000 tons CO₂-e;

Test case: 14,000,000 tons CO₂-e;

Net reduction in emission due to fuel treatment: 3,000,000 tons CO₂-e.

Emissions from treatment: equipment: 1,220,000 tons CO₂-e;

Underburning: 1,700,000 tons CO₂-e

Utilization: biomass energy, wood products.

However, the model did not account for:

- emissions from sawlog production or
- any potential emissions or credits for offsetting natural gas

These could be calculated, respectively, as net emissions of:

- 37,603,847 tons CO₂-e for wood products (based on wood retirement rate of 64.5% over 100 years), and
- 27,613,800 tons CO₂-e for emissions from biomass energy (based on offsetting natural gas)

Reassessment Conclusions: When emissions from sawlog utilization and retirement and biomass efficiency are incorporated, the test case has more than five times higher emissions than the reference case:

Reference case: 17,000,000 tons CO₂-e;

Test case: $14,000,000 + 37,603,847 + 27,613,800 = 79,217,647 \text{ tons CO}_2-e;$

Net increase in emissions due to fuel treatment: 62,217,647 tons CO₂-e.

Hurteau, Koch, and Hungate (2008)

Carbon protection and fire risk reduction: toward a full accounting of forest carbon offsets.

Publication Conclusion: The authors state that their "back of the envelope' calculations indicate that massive CO₂ emissions from wildfire are avoidable in forests that have historically been characterized by frequent, low-severity fire."

Forest types: Ponderosa pine and mixed conifer forests in AZ, CO, OR, and CA

Treatments: Looked at four large forest fires (Rodeo-Chediski in AZ, Hayman in CO, Biscuit in OR and CA, and McNally in CA), and modeled the effects that treatments prior to fire would have had. Hypothetical treatment was a thin from below, removing the majority of small diameter trees.

Stocks: N/A (compared treatment and fire emissions, rather than calculating stocks)

Fire risk: 100%, as the study addressed fires that had occurred

Wildfire emissions: 4.2-6.1 MMTCO₂e from live tree emissions, across the four fires; modeled treatment could have reduced the emissions more than 90%

Emissions from treatment: Modeled thinning removed 3.9 MMTCO₂e across the four fires; study did not account for emissions from thinning and transportation

Utilization: not included, as thinned material was non-merchantable, though biomass energy may be an option

Reassessment Conclusions: The study looked at major stand replacing fires that had occurred. In reality, as has been shown, the risk of fire is relatively low and the risk of a large-scale crown fire is lower still. Emissions could have been reduced by more than 90%; however, the risk of fire is very unlikely to exceed 3% per year (and is likely to be less than 1% as was found in Oregon and California). When these factors are integrated in the analyses it is unlikely that a net emission reduction could result from treatment.

Wiedinmyer and Hurteau (2010)

Prescribed fire as a means of reducing forest carbon emissions in the Western United States.

Publication Conclusion: The study concludes that prescribed burning could reduce fire emissions in the western U.S. by 18-25%.

Forest type: Western forests – multiple forest types

Treatments: Emissions from prescribed burning were modeled on western forests that historically had fairly frequent fire return intervals and low or mixed severity effects.

Stocks: N/A

Fire risk: 100%, as the study addressed fires that had occurred

Wildfire emissions: Annually averaged state-wide wildfire emissions ranged from 1-18 MMTCO₂/yr from 2001-2001 across 11 western states.

Emissions from prescribed fire: Annually averaged state-wide prescribed fire emissions ranged from 1-14 MMTCO₂/yr from 2001-2008 across the same states.

Emissions from treatment: same as above, as treatment consisted entirely of prescribed burning

Utilization: N/A

Reassessment Conclusions: The findings are based on the replacement of wildfire with prescribed fire, presupposing that the location of wildfires could be predicted accurately before their occurrence, allowing for management with prescribed fire only in locations that would otherwise burn in a wildfire. Modeling techniques do not yet allow us to know exactly where fires will occur, necessitating large areas of treatment in order to capture future uncertain area of wildfire. If the prescribed fire emissions are multiplied by a 20-200 factor to reflect the additional area that would have to be treated in order to be confident of capturing future wildfires (reflecting a fire risk of between 0.5 and 5% / yr) then the emissions from

prescribed fires would range between 20 and 2,800 MMTCO₂/yr (clearly exceeding the emissions from wildfires).³

Robards and Wickizer (2010)

Demonstration of the Climate Action Reserve Forestry Protocols at LaTour Demonstration State Forest, WESTCARB Final Report.

Publication Conclusion: This study shows a total expected emission reduction of 12,387.3 tC (47,070 t CO₂-e) over the life of the project (100 years)

Forest type: Ponderosa pine, mixed conifer, white fir, red fir

Treatments: Creation of a shaded fuel break, retaining a post-harvest basal area of 50 ft²/ac, and reducing ground and ladder fuels.

Stocks: 98,616.9 tons of carbon across entire project area

Fire risk: 3% (assumed not calculated)

Wildfire emissions: 30% loss of carbon stocks in extreme fire conditions, 20% loss in high severity weather conditions, and 10% loss in moderate severity weather conditions (assumed not calculated)

Emissions from prescribed fire: N/A

Emissions from treatment: 2,109.4 tons of carbon across fuel breaks (8,031 t CO₂-e).

Utilization: N/A

Reassessment Conclusions: The study relies on highly optimistic assumptions:

- First, the study uses a fire risk that is significantly higher than commonly accepted
 annual burn probabilities including burn probabilities calculated independently by
 UC Berkeley, Winrock and Dr Sam Sandberg in the course of this study. LaTour
 State Forest is in Shasta County so the authors can be confident that the actual fire
 risk is <0.75%/yr;
- Second, it is assumed that installation of a fuel break prevents fire from even reaching half of the project area. Essentially this states that a 300 ft wide fuel break will prevent the passage of any wildfire;
- Third, it is assumed that there is no regrowth of trees whatsoever following a wildfire.

³ If such large-scale prescribed burning were undertaken then through time the benefit would grow as all areas would be treated within the first years and ultimately reduced emissions would result from wildfires in the absence of additional treatment emissions (or at least just with the diminished treatment emissions that arise with retreatment).

The report states that, even with these assumptions with regard to decrease in fire incidence due to the fuel break and the lack of regrowth, there is a break even in terms of emissions in baseline and project cases with an annual fire risk of 0.44% (close to what might be expected for the region).

CHAPTER 7: Summary and Recommendations

Discussion/Conclusions

Reducing emissions from fire could be an important contribution to reducing CO₂ emissions overall, yet the reduction of carbon stocks in hazardous fuels treatments, combined with the low annual probability of fire on a given acre of land in the study region of northern California and southern Oregon prevent the generation of viable carbon offsets from such treatments. In the case of the standard fuels treatments for mixed conifer forests in northern California and southern Oregon which served as the field test for this research, treatments clearly led to significant increased net emissions.

These conclusions may be subject to change in the future if new technologies are developed for fuel removal, energy generation through fuel combustion or enhanced modeling techniques are developed for predicting the location of future wildfires.

These findings should in no way be read as an argument for halting fuel treatments. Reducing the risk of fire is a critical activity for many other reasons, including enhancing forest health, maintaining wildlife habitat, and reducing risk to life and property, and as such is an activity that must continue though unfortunately without financial support from greenhouse gas emission reduction offsets.

It may be desirable to return forests to a condition that more closely resembles pre-suppression forests. Such forests are likely to experience fewer high severity fires, and therefore release less carbon dioxide in the event of a wildfire. However, achieving these conditions will likely require the short term release of carbon dioxide currently stored as forest biomass. Therefore, it is not likely that this type of management presents a carbon offset project type, but rather a desirable overall management strategy that may lead to lower but more stable carbon stocks.

In addition, in today's world where actions to curb atmospheric greenhouse gas concentrations are growing more urgent, an accurate accounting of all emission sources at national, regional and local scales is important. The work completed here allows a better understanding of the relative emissions that arise from hazardous fuel treatments and wildfires. This may become increasingly important as fire risk is California has been projected to increase between 12 and 53 percent by the end of the century (We sterling and Bryant, 2008). Even though current technologies make it difficult for fuels treatments to lead to net emission reductions, it is important for planners to understand relative greenhouse gas emissions to be able to design treatments in a way that minimizes emissions while maximizing benefits to local populations and forest health and habitats.

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Supplemental Materials



FINAL FUELS MANAGEMENT REPORT ON WESTCARB MANAGEMENT PILOT ACTIVITIES IN SHASTA COUNTY, CALIFORNIA

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Arnold Schwarzenegger Governor

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Prepared For:

California Energy Commission
Public Interest Energy Research Program

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PIER PROJECT REPORT

July 2010 CEC-XXX-XXX-XXX



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Preface

The Public Interest Energy Research (PIER) Program supports public interest energy research and development that will help improve the quality of life in California by bringing environmentally safe, affordable, and reliable energy services and products to the marketplace.

The PIER Program, managed by the California Energy Commission (Energy Commission) conducts public interest research, development, and demonstration (RD&D) projects to benefit the electricity and natural gas ratepayers in California. The Energy Commission awards up to \$62 million annually in electricity-related RD&D, and up to \$12 million annually for natural gas RD&D.

The PIER program strives to conduct the most promising public interest energy research by partnering with RD&D organizations, including individuals, businesses, utilities, and public or private research institutions.

PIER funding efforts are focused on the following RD&D program areas:

- Buildings End-Use Energy Efficiency
- Industrial/Agricultural/Water End-Use Energy Efficiency
- Renewable Energy Technologies
- Environmentally Preferred Advanced Generation
- Energy-Related Environmental Research

This Final Report on WESTCARB Fuels Management Pilot Activities in Shasta County, California is a report for the West Coast Regional Carbon Sequestration Partnership – Phase II (contract number MR-06-03L, work authorization number MR-045), conducted by Winrock International. The information from this project contributes to PIER's Energy-Related Environmental Research program.

For more information on the PIER Program, please visit the Energy Commission's Web site at www.energy.ca.gov/pier or contact the Energy Commission at (916) 654-5164.

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Abstract

This report summarizes efforts by Winrock International, WM Beaty and Associates, and other Shasta County, California partners to implement hazardous fuel reduction/biomass energy pilot activities in WESTCARB Phase II (2006-10). Wildfire is a significant source of GHG emissions in California and throughout the WESTCARB region. WESTCARB developed methodologies to evaluate, validate and demonstrate the potential of reducing hazardous biomass for biomass energy to contribute to GHG mitigation and adaptation. The report describes hazardous fuel reduction pilot activities on private lands in Shasta County; pre- and post-treatment measurements to quantify forest carbon impacted by treatment and/or fire; and analysis of data from these pilots to determine the net GHG impact of the fuel reduction treatments.

Keywords: Carbon, sequestration, hazardous fuel reduction, forest, Shasta County

Executive Summary

Introduction

The West Coast Regional Carbon Sequestration Partnership (WESTCARB), led by the California Energy Commission, is one of seven US Department of Energy regional partnerships working to evaluate, validate and demonstrate ways to sequester carbon dioxide and reduce emissions of greenhouse gases linked to global warming.

Earlier analyses by Winrock showed wildland fire to be a substantial source of greenhouse gas (GHG) emissions throughout the region. Actions to reduce hazardous fuel loads, so as to reduce the probability, areal extent, or severity of wildfires, could result in lower net GHG emissions when compared to a baseline scenario without such treatments. Fuel reduction may also contribute to carbon sequestration by enhancing forest health or growth rates in post-treatment stands. Finally, for treatments where fuel removal to a biomass energy facility is feasible, additional GHG benefits may be created by substituting the biomass for fossil fuel rather than leaving the biomass in the forest to decompose.

Hazardous fuel reduction/biomass energy pilot activities were implemented in the two WESTCARB terrestrial pilot locations, Shasta County, California and Lake County, Oregon. These projects provide real-world data on carbon impacts of treatments, costs, and project-specific inputs to a related WESTCARB task, in which Winrock International and the WESTCARB Fire Panel are working to investigate whether the development of a rigorous methodology to estimate GHG benefits of activities to reduce emissions from wildland fires is feasible.

Purpose

This report provides results from the WESTCARB Phase II hazardous fuel reduction pilot activities in Shasta County, California.

Project Objectives

The overall goal of WESTCARB Phase II is to demonstrate the region's key carbon sequestration opportunities through pilot projects, methodology development, reporting, and market validation. WESTCARB research will inform policymakers, communities, and businesses on how to invest in carbon capture and storage technology development and deployment to achieve climate change mitigation objectives.

The specific objectives of the Phase II Shasta County fuel reduction pilots are to investigate the feasibility of fuels-treatment-based terrestrial sequestration by conducting pilot projects in a representative West Coast forest; compile information on site conditions, fuel treatment prescriptions, and costs; and inform and field-test the WESTCARB fire GHG emissions methodology.

Methodology for measuring impacts of hazardous fuels treatments

Pre- and post-treatment measurements were made on three fuels treatment projects in Shasta County, California: Berry Timber, Davis, and HH Biomass. The fuel reduction activities were located in the southeast corner of the county; all three projects were located on privately owned land. These projects

involved removal of non-commercial biomass and sawtimber with the overall objective of reducing fuel loading and risk of catastrophic wildfire. Treatments also included chipping and removal of biomass fuel to a biomass energy plant. The actual fuels treatments were not initiated under WESTCARB support, but they provided an opportunity to conduct on-the-ground measurements of actual hazardous fuel reduction efforts.

Data were collected in a total of 35 plots (15 on Davis, 9 on HH, and 11 on Berry Timber). Pre- and post-treatment measurements on these plots addressed live trees greater than 5 cm diameter at breast height, canopy density, standing and lying dead wood, understory vegetation, forest floor litter and duff. These represent the forest carbon pools that are likely to be affected by fire, treatment, or both, and so are critical to the accounting of hazardous fuel reduction treatment impacts and potential wildfire impacts on forest carbon.

These measurements were used to determine the carbon stocks before and after treatment and before and after a potential wildfire, for each project area. Growth modeling was conducted with the Forest Vegetation Simulator for both with and without treatment stands. Emissions from a potential fire were modeled in both with- and without-fuels treatment scenarios using both the Fuel Characteristic Classification System and the Forest Vegetation Simulator fire and Fuels Extension (FVS-FFE). FVS was also used to project growth on burned stands, incorporating the impacts of fire on the future stand.

The substitution of harvested biomass for existing energy sources was taken into account where fuels were extracted to a biomass energy plant. Board feet of timber harvested was converted to metric tons of carbon, with retirement rates applied.

Project Outcomes

Berry Timber

Treated stands without wildfire have total stocks of 51.2 tons of carbon per acre, with 44.2 t C/ac in the same stands following a wildfire, including carbon stored in long term wood products and energy offsets.

Incorporating the risk of fire of 0.64% to calculate net emissions or removals, the fuels treatment on the Berry Timber project resulted in an effective immediate net carbon emission of 69.2 t CO_2 -e/ac (18.9 tons of carbon per acre).

In the absence of a wildfire, the fuels treatments and commercial harvest result in short term emissions of 83.2 t CO_2 /ac and emissions of 116.2 t CO_2 /ac over 60 years (Table A1).

Table A1. Net short and long term emissions from fuels treatment without fire on Berry Timber in tons of carbon dioxide per acre (+ = removals; - = emission)

	Short term 10 years	Long term 60 years
Biomass energy	-4.5	-4.5
Commercial timber	3.7	2.6
Treatment emissions	-86.9	-118.8
NET	-83.2	-116.2

For the treatment to yield benefits to the atmosphere, the emissions from treatments will need to be offset by reductions in emissions from a potential wildfire hitting the area. In order for the treatment to have an impact, such a fire would have to occur before fuels have returned to hazardous conditions, at which point it will be necessary to re-treat the forest. According to the FVS-modeled results, if a wildfire were to occur in the year of treatment, after 10 years the net emissions from treatment would be 31.5 t CO₂/ac.

Davis

Including carbon stored in long term wood products and energy offsets, treated stands without wildfire have total stocks of 47.9 tons of carbon per acre compared to stocks of 38.7 t C/ac in treated stands following a wildfire.

Incorporating the risk of fire of 0.64% to calculate net emissions or sequestration (section 2.2.6), the fuels treatment on the Davis project resulted in a net carbon emission in year one of 11.0 t CO_2 -e/ac (3.0 t C/ac).

In the absence of a wildfire, the fuels treatments and commercial harvest result in short term emissions of 39.2 t CO_2 /ac and emissions of 60.1 t CO_2 /ac over 60 years (Table A2).

Table A2. Net short and long term emissions from fuels treatment without fire on Davis in tons of carbon dioxide per acre (+ = removals; - = emission)

	Short term 10 years	Long term 60 years
Biomass energy	-15.4	-15.4
Treatment emissions	-23.8	-44.7
NET	-39.2	-60.1

For the treatment to yield benefits to the atmosphere, the emissions from treatments will need to be offset by reductions in emissions from a potential wildfire hitting the area. In order for the treatment to have an impact, such a fire would have to occur before fuels have returned to hazardous conditions, at

which point it will be necessary to re-treat the forest. According to the FVS-modeled results, if a wildfire were to occur in the year of treatment, after 10 years the net emissions from treatment would be 20.2 t CO_2/ac .

HH biomass

Including carbon stored in long term wood products and energy offsets, treated stands without wildfire have total stocks of 55 tons of carbon per acre compared to a stock of 45.3 t C/ac in treated stands following a wildfire.

Incorporating the risk of fire of 0.64% to calculate net emissions or sequestration (section 2.2.6), the fuels treatment on the HH Biomass project resulted in a net carbon emission in year one of 32.3 t CO_2 -e/ac (8.8 t C/ac).

In the absence of a wildfire, the fuels treatments and commercial harvest result in short term emissions of 83.6 t CO_2 /ac and emissions of 90.5 t CO_2 /ac over 60 years (Table A3).

Table A3. Net short and long term emissions from fuels treatment without fire on HH biomass in tons of carbon dioxide per acre (+ = removals; - = emission)

	Short term 10 years	Long term 60 years
Biomass energy	-23.8	-23.8
Treatment emissions	-59.8	-66.7
NET	-83.6	-90.5

For the treatment to yield benefits to the atmosphere, the emissions from treatments will need to be offset by reductions in emissions from a potential wildfire hitting the area. In order for the treatment to have an impact, such a fire would have to occur before fuels have returned to hazardous conditions, at which point it will be necessary to re-treat the forest.

According to the FVS-modeled results, if a wildfire were to occur in the year of treatment, after 10 years the net emissions from treatment would be $41.4 \text{ t CO}_2/\text{ac}$.

Conclusions and Recommendations

In all three projects, the treatments resulted in overall carbon emissions. This result clearly has negative implications for the future potential of fuels treatments as a carbon projects offset category. Within the treated areas, all three projects had significant net emissions when considering treatment and the risk of a potential wildfire. Davis experienced the lowest emissions, but the treatment on Davis did not decrease fire intensity. If a fire were to occur in the year of treatment, all projects would still experience net emissions, though the impact of treatment emissions would be approximately halved in all cases.

All three of the pilots led to a projected decrease in crown fire potential, which decreases fire severity and size. While treatments lead to net carbon emissions in both the short and long term in all three

projects, there are, of course, additional benefits to fuels treatments, such as increased ability to successfully fight fires and decreased cost of fire fighting; reduced loss of life and property; and reduced potential damage to wildlife habitat.

The results from this study in combination with the paired study in Lake County and the allied study in Mendocino National Forest underlie the unsuitability of fuels treatment as a potential greenhouse gas offset generating activity. Instead we argue the shift should be made to policies minimizing greenhouse gas emissions from wildfires and from fuel treatments while minimizing wildfire risks to lives, homes, wildlife habitat, and livelihoods in the WESTCARB region.

1.0 Introduction

1.1 Background and overview

The West Coast Regional Carbon Sequestration Partnership (WESTCARB), led by the California Energy Commission, is one of seven US Department of Energy regional partnerships working to evaluate, validate and demonstrate ways to sequester carbon dioxide and reduce emissions of greenhouse gases linked to global warming. Terrestrial (forestry and land use) sequestration options being investigated include afforestation, improved management of hazardous fuels to reduce GHG emissions from wildfires, biomass energy, and forest management. Shasta County, California and Lake County, Oregon were chosen for Phase II terrestrial sequestration pilot projects because of the diversity of land cover types present, opportunities to implement the most attractive terrestrial carbon activities identified in Phase I, and replication potential elsewhere in the WESTCARB region.

Earlier reports identified fire as a significant source of GHG emissions throughout the WESTCARB region. Estimated emissions from fires for the 1990-96 analysis period were: 1.03 MMTCO₂e per year on average for Oregon (Pearson et al 2007a); 1.83 MMTCO₂e per year for California (Pearson et al 2009); 0.18 MMTCO₂e/yr for Washington (Pearson et al. 2007b); and 0.47 MMTCO₂e/yr for Arizona (Pearson et al. 2007c).

The estimated baseline GHG emissions helped focus attention in Phase II on the questions: can actions by landowners to manage forest fuel loads be shown to produce measurable GHG reductions by decreasing the risk, severity, or extent of catastrophic wildfires? If so, can scientifically rigorous methods for measuring, monitoring, and verifying these GHG reductions serve as the basis for new protocols and market transactions, ultimately allowing landowners who reduce hazardous fuels to receive "carbon credit" revenues and improving the cost-effectiveness of fuel reduction? To explore these questions, hazardous fuel reduction (and where possible, removal of fuel for biomass energy generation) was chosen as a WESTCARB Phase II pilot activity in Shasta and Lake counties, and the WESTCARB Fire Panel was formed to develop fire GHG methodologies and protocols as needed.

1.2 Project Objectives

The overall goal of WESTCARB Phase II is to validate and demonstrate the region's key carbon sequestration opportunities through pilot projects, methodology development, reporting, and market validation. WESTCARB research will inform policymakers, communities, and businesses on how to invest in carbon capture and storage technology development and deployment to achieve climate change mitigation objectives.

The specific objectives of the Phase II Shasta County fuel reduction pilots are to:

- Verify the feasibility of fuels-treatment-based terrestrial sequestration by conducting pilot projects in representative West Coast forests;
- Compile information on site conditions, fuel treatment prescriptions, and costs;
- Inform and field-test the WESTCARB fire GHG emissions methodology by:

- o Collecting measurements of real-world fuel treatments to quantify:
 - the carbon stocks available to be burned before and after treatment,
 - the direct impacts of fuel treatments on carbon stocks in different carbon pools (e.g. increases in dead wood, decreases in dense growth), and
 - the fuel removed from the forest for potential biomass energy applications;
- Providing input data for fire models used to simulate fire behavior and emissions in the baseline (without-treatment) and with-treatment scenarios.

1.3 Report Organization

The report is organized into four sections: 1. Introduction; 2. project approach; 3. results; and 4. conclusions/ recommendations. Section 2 summarizes the private- and federal-lands fuel treatments chosen for study as WESTCARB pilot activities, and methods used for pre- and post-treatment measurements and data analysis. Section 3 provides results of those measurements and analyses. Section 4 discusses the findings and provides recommendations based on this research.

2.0 Project Approach

2.1 Fuel reduction project locations and descriptions

Pre- and post-treatment measurements were made on three fuels treatment projects in Shasta County, California. These projects all involved removal of non-commercial biomass and/or sawtimber with the overall objective of reducing fuel loading and risk of catastrophic wildfire. All also involved chipping and removal of biomass fuel to the Wheelabrator Shasta biomass energy plant in Anderson, California. The actual fuels treatments were not initiated under WESTCARB support, but they provided an opportunity to conduct on-the-ground measurements of actual hazardous fuel reduction efforts.

2.1.1 Fuel reduction on Berry Timber project (PG&E)

Location

The project area encompassed 845 acres and is shown in the map in Figure 1. It is located just southeast of the town of Shingletown in Shasta County, CA. The legal description is portions of Sections 25, 34, 35 & 36 Township 31 North, Range 1 East, M.D.B.&M. The forest type of the project area is Sierra Nevada Mixed Conifer, (Ponderosa Pine, Sugar Pine, White Fir, Douglas-fir and Incense Cedar.) Minor amounts of California Black Oak reside on the project area as well.

Treatment

The PG&E Berry timber harvest operation was conducted in the summer of 2007.

The area was treated under an individual tree selection silivicultural prescription focusing on the merchantable trees 10 inches diameter at breast height (dbh) and greater. Trees identified for harvest were trees showing signs of distress, mechanical defect, evidence of insects/disease and trees growing too close together. Biomass thinning of trees between 4 and 9 inches (dbh) was conducted on a small portion of the project area. Trees were extracted intact and tops and branches of commercial trees chipped and hauled to the Wheelabrator biomass energy facility along with the pre-commercial trees. A total of 3.461 million board feet of sawlogs were harvested from the project. A total of 173 loads of biomass were shipped to Wheelabrator Biomass Energy Plant in Anderson, comprised of 4,357 green tons of biomass with 39.3% moisture content (2,644 bone dry tons). The logging method was mechanical ground based, utilizing whole tree harvesting. All

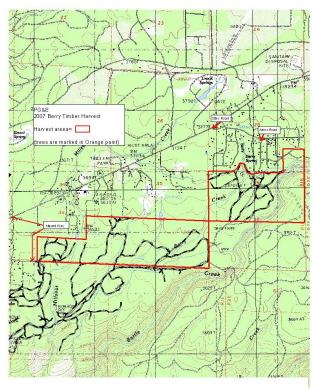


Figure 1. Map of harvest area for PG&E Berry Timber project

tree tops, limbs and biomass were chipped on the landing and sent to Wheelabrator Shasta Energy.

2.1.2 Fuel reduction on Davis Biomass project (W.M. Beaty & Associates, Inc. / Brooks Walker et al)

Location

The Davis Biomass project is located approximately three miles east of Whitmore, CA at approximately 3,000 foot elevation on the west slope of the Southern Cascades on forestlands managed by W.M. Beaty & Associates, Inc. The project area consists of 2,200 acres of uneven-age natural stands of mixed conifer and ponderosa pine along with a portion of a 30 year old ponderosa pine plantation that was established after the 1977

Whitmore Fire.

Treatment



Figure 2: Loading thinned trees for delivery to biomass energy plant

The objectives of the project were to thin small overcrowded trees in the understory of the conifer forest to improve the health and vigor of the remaining trees and reduce hazardous fuel ladders and

fuel loading. Trees targeted for removal included suppressed trees between 4 and 12 inches (dbh) with poor live crown ratios. Vigorous trees of this size class with good live crown ratios were retained along with all live trees of larger size classes (12 inch dbh and greater). Although the logging contractor was not required to cut trees less than 3 inches dbh, some were thinned out to facilitate removal of the target trees.

The treatment was completed over three years (2007 – 2009) with the removal of 1,804 chip van loads totaling 24,998 bone dry tons (BDTs) that were delivered to Wheelabrator Shasta Energy Co., Inc. in Anderson for electricity generation. While this treatment might have been completed in one long operating season, the following factors contributed to extending the treatment over three operating seasons:

- the onset of early fire seasons,
- operators being called away to other jobs, and
- the inability to operate in this area during the winter.

As fire hazards increased with the onset of each summer, each year the humidity levels dropped below 20% by 9 or 10 o'clock in the morning and fire hazard restrictions forced operational shutdowns. However, the objectives of the project were accomplished by thinning the understory to promote residual stand health and vigor and reduce the risk of catastrophic loss by reducing fuel loads and ladder fuels which will aid fire suppression efforts should a wildfire occur.

2.1.3 Fuel reduction on HH Biomass project (W.M. Beaty & Associates, Inc. / Red River Forests Partnership and Bank of the West, Trustee)

Location

The HH Biomass project is located approximately two miles north of Shingletown, CA at approximately 3,500 foot elevation on mixed conifer forestlands managed by W.M. Beaty & Associates, Inc.

Treatment

Objectives of the 1,445-acre biomass thin project were to increase stand health and vigor, reallocate the species composition to mimic a more "natural" historic forest and to reduce the risk of loss from catastrophic wildfire by reducing ladder fuels and total fuel loading. Trees targeted for removal included suppressed trees between 4 and 12 inch dbh with poor live crown ratios.



Figure 3. Stand in HH Biomass project after thinning

Except for a special "Shaded Fuel Break" prescription within 100 feet of the main roads, vigorous trees of this size class with good live crown ratios were retained along with all live trees of larger size classes (12 inch dbh to 36+ inches dbh). Within 100 feet of some main roads almost all understory trees were

thinned out and the re-sprouting brush was then treated to create a "Shaded Fuel Break". Although the logging contractor was not required to cut trees less than 3 inches dbh, some were thinned out to facilitate removal of the target trees.

The treatment was completed over three years (2007 – 2009) with the removal of 1,917 chip van loads totaling 26,104 bone dry tons (BDTs) that were delivered to Wheelabrator Shasta Energy Co., Inc. in Anderson for electricity generation. The objectives of the project were accomplished by thinning the understory to promote residual stand health and vigor and to reduce the risk of catastrophic loss by decreasing fuel loads and ladder fuels which will aid fire suppression efforts should a wildfire occur.

2.2 Methods

2.2.1 Field measurements before and after fuel treatments

The location of field sampling plots was pre-assigned in a geographical information system (GIS) prior to fieldwork (Figures 4a, b, c). Data were collected in a total of 35 measurement plots¹ (15 on Davis, 9 on HH, and 11 on Berry Timber). Plot coordinates were generated randomly in advance of the field work. The field team navigated to the pre-assigned points. Plot measurements were taken in accordance with USFS General Technical Report NRS-18 (Pearson et al. 2007d), and included the following measurements at each plot location within fuel treatment units:

- All trees >5 cm diameter at breast height, measured in nested plots and marked for post-treatment measurements;
- Canopy density, tree heights, and height to live crown, as inputs to fire behavior models;
- Standing dead wood;
- Lying dead wood, measured along transects (plus dead wood density from collected samples).
- Understory vegetation, forest floor litter and duff, measured in clip plots;

These represent forest dimensions that will influence fire severity and the forest carbon pools that may be affected by fire, treatment, or both. The protocols used for these measurements are described in Annex A.

¹ The number of plots was the result of available resources and field time rather than being statistically calculated.

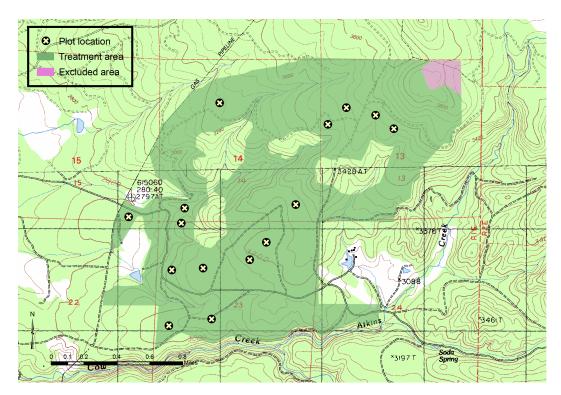


Figure 4a. Davis Mountain treatment area and plots

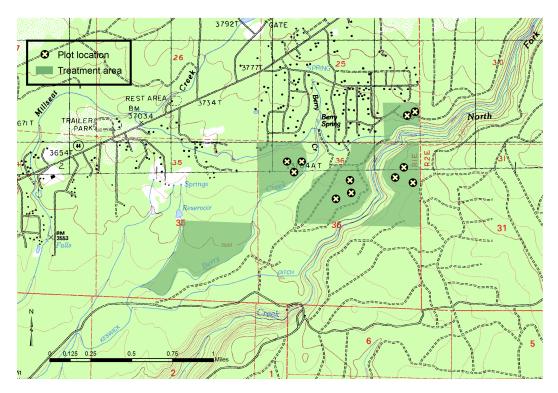


Figure 4b. Berry Treatment area and plots

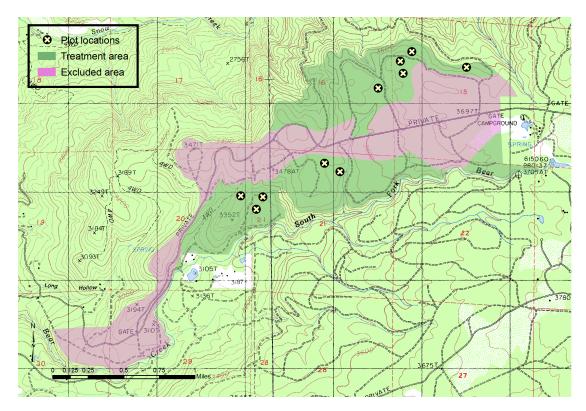


Figure 4c. HH treatment area and plots

The date of treatment at each site and the dates of pre- and post-treatment measurements by Winrock/Western Shasta RCD crews are shown in Table 1. In order to quantify the effects of treatment on the same carbon pools, the post-treatment measurements were conducted shortly after treatments were completed, on the same plots used for pre-treatment measurements, following a measurement protocol similar to pre-treatment fieldwork. The one difference in the post-treatment measurements was that tree diameters were not measured; instead, trees marked during pre-treatment measurements were counted and assumed to have the same diameter.

Table 1. Dates of fuel treatment and pre- and post-treatment measurements for the three Shasta County fuel treatment sites

Location		Date		
	Pre-Treatment Measurement	Treatment	Post-Treatment Measurement	
Davis Mountain	June 2007	2007-2009	June 2009	
HH Biomass	June 2007	2007-2009	June 2009	
Berry Timber	June 2007	July – August 2007	September 2007	

The purpose of the measurements was to identify, in real as opposed to modeled forests, the carbon stocks available to be burned before and after treatment, the direct impacts of fuel treatments on carbon stocks in different carbon pools (e.g. increases in dead wood, decreases in dense growth), and the fuel removed from the forest for biomass energy during treatment. Measurements also provided input data for fire models used to simulate fire behavior and emissions in the baseline (without-treatment) and with-treatment scenarios.

The total carbon stocks were determined using the standard allometric equations of Forest Vegetation Simulator Fire and Fuels Extension Inland California and Southern Cascades variant².

2.2.2 Fire Modeling

Based on the field data disaggregated by carbon pool, emissions from a potential fire were modeled in both with- and without-fuels treatment scenarios. The modeling was conducted using two separate approaches.

- 1. The FCCS program (Fuel Characteristic Classification System) was developed by the Pacific Northwest Research Station to capture the structural complexity and geographical diversity of fuel components across landscapes and to provide the ability to assess elements of human and natural change. FCCS is a software program that allows users to access a nationwide library of fuelbeds or create customized fuelbeds. The fuelbeds are organized into six strata: canopy (trees), shrubs, nonwoody vegetation, woody fuels (lying deadwood and stumps), litter-lichen-moss, and ground fuels (duff and basal accumulations). FCCS calculates the relative fire hazard of each fuelbed, including crown fire, surface fire behavior, and available fuel potentials. It also reports carbon storage by fuelbed category and predicts the amount of combustible carbon in each category.³
- **2.** In addition to the FCCS modeling, fire effects were modeled using the **Forest Vegetation Simulator Fire and Fuels Extension** (FVS-FFE). FVS provides different output to FCCS and FVS can be used to project growth, incorporating the impacts of fire on the future stand.

The two models produced slightly different results, as they use different modeling methodologies and different biomass equations. They also produce somewhat different output. Reported outputs from FCCS include flame length in feet; crown fire potential as a scaled index from 0-9; rate of spread in feet per minute; and carbon consumed for live canopy, dead wood, and total. Reported results from FVS-FFE include flame length in feet; the crowning index in miles/hour; and total carbon consumed. Results for both prescribed fire and wildfire are reported from FCCS, while only wildfire is reported from the FVS-FFE results.

² More information, including the FVS User's Guide and variant descriptions, are available at http://www.fs.fed.us/fmsc/fvs/index.shtml.

³ More information is available at the FCCS website: http://www.fs.fed.us/pnw/fera/fccs/. The modeling was conducted by Dr. David "Sam" Sandberg – Emeritus of the PNW Research Station Fire and Environmental Application Team.

Although FVS uses a somewhat simpler methodology than FCCS for projecting fire impacts, it is based on established fire models and allows for growth projections. In order to address growth over time, FVS projections are used throughout the results, but FCCS output is presented to demonstrate the range of potential fire emissions.

2.2.3 Fire Risk

Annual burn probability is difficult to project accurately, as it is a factor of the likelihood of ignition and the conditions on the ground at the time of ignition, including fuels, climate, temperature, and topography (see Finney, 2005). Saah *et al.* (2010) determined the relative fire probability and observed annual burn probability for Shasta County, which were used to identify a potential annual burn probability of 0.64% (Eric Waller, 2010, UCB CFRO, pers. comm.). It is important to note that this is a generalized probability and is not based specifically on pre- and post-treatment conditions for these projects, but rather for Shasta County as a whole.

2.2.4 Growth Modeling

Stand growth, both with- and without-treatment and considering all pools, was modeled with the US Forest Service's Forest Vegetation Simulator (FVS), using the Inland California and Southern Cascades variant. The standard allometric equations in the Fire and Fuels Extension (FFE) of FVS were used to produce biomass and carbon reports in conjunction with forest growth. Data from both the 2007 and 2009 inventories were used, with the pre-treatment inventory year counted as year zero to compare with and without treatment scenarios. Growth was projected over a 60 year period, and did not include any additional future treatments. To incorporate the effects of wildfire on growth, FVS-FFE was also used to model wildfire behavior.

2.2.5 Modeled Scenarios

For both fire and growth modeling, four different scenarios were modeled for all three projects. Each scenario includes the following carbon pools: aboveground live, belowground live, standing dead, and lying dead. The treated scenarios also include carbon stored in merchantable timber after 100 years. To simplify calculations, the emissions arising from wood product conversion and subsequent retirement are included at the beginning of the project. The treatment scenarios also incorporate average emissions from equipment use.

	Untreated	Treated
No Wildfire	1.Untreated,	3.Treated,
NO Whalle	no fire	no fire
Wildfire	2.Untreated,	4.Treated,
Wilding	wildfire	wildfire

- *Scenario 1* gives the situation where there is no treatment or fire. At time zero it represents simply the carbon stocks (tons of carbon per acre) prior to treatment.
- Scenario 2 is the carbon emissions and remaining stocks following a wildfire on untreated lands.
- Scenario 3 is the carbon stocks remaining after the treatment, incorporating any emissions that were a result of treatment activities but in the absence of any fire.
- Scenario 4 is the carbon emissions and remaining stocks following a wildfire on treated lands.

2.2.6 Biomass Accounting

We assumed that biomass harvested from project areas and burned to produce energy offsets energy that would otherwise be derived from fossil fuels. In California power generation is dominated by natural gas with small contributions from clean energy/nuclear and coal. In January 2007 the California Public Utilities Commission established a performance standard that all new long-term baseload generation must meet (http://docs.cpuc.ca.gov/Published/NEWS_RELEASE/63997.htm). As this performance standard is equivalent to the minimum standard required for any new power generation in California it is considered to be a conservative comparison for this analysis. The CPUC performance standard is equal to 1,100 pounds of carbon dioxide emitted for each Megawatt hour of electricity produced, an amount equivalent to 0.499 metric tons of carbon dioxide.

Literature⁴ and our partners at Wheelabrator indicate that one bone dry ton of biomass produces one MWh of electricity. One bone dry ton is 0.5 bone dry ton of carbon or 1.833 tons of carbon dioxide. Each ton of biomass extracted for biomass energy therefore effectively emits:

$$1.833 - 0.499 = 1.334 \text{ t CO}_2^5$$

⁴ cf. http://bioenergy.ornl.gov/papers/misc/energy conv.html,
http://groups.ucanr.org/WoodyBiomass/documents/InfoGuides12929.pdf

This subject often leads to confusion. Many interpret the fact that biomass is replaceable in the way that fossil fuels are not to mean that all biomass burned has no net impact on the atmosphere. But as the paragraph above demonstrates, burning biomass does increase the greenhouse gases resident in the atmosphere. Burning biomass might prevent emissions from fossil fuels, but this is by no means permanent. What is being achieved is a delay in the date at which all fossil fuels will be used. It is critical to focus on the atmosphere, i.e. does the project cause an increase or decrease in the concentration of carbon dioxide in the atmosphere? In this case, burning biomass

The assumption of many (including the IPCC) is that biomass burned to produce electricity is carbon neutral. The argument is that all biomass that is burned was once grown, and so one MWh of electricity derived from biomass leads to a positive emissions avoidance of 0.499 t CO_2 (i.e., avoiding natural gas emissions). This would be true if the biomass were grown as part of the project in a plantation, where in the absence of the project the biomass being burned would never have been sequestered from the atmosphere. However, natural forests in California are not plantations. In the absence of the project, CO_2 was sequestered out of the atmosphere by the forest biomass. In the project case, this biomass is burned and released into the atmosphere. In the baseline the biomass remains sequestered in the forest. Thus what the atmosphere "sees" is a net increase in carbon dioxide because of the project. However, because of the project some amount of natural gas does not need to be burned to produce electricity. Specifically, as shown above, for each 1.833 t CO_2 released to produce 1 MWh of electricity through biomass from hazardous fuels, $0.499 \text{ t } CO_2$ are saved due to natural gas not having to be burned. Therefore, burning hazardous fuels rather than natural gas results in a net emission of 1.334 t CO_2 .

Because of the biomass removal treatment some amount of natural gas does not need to be burned to produce electricity. Specifically, as shown above, for each 1.833 t CO_2 released to produce 1 MWh of electricity through biomass from hazardous fuels, 0.499 t CO_2 are saved due to natural gas not having to be burned. This is equivalent to 27.2% of the net emission being offset.

2.2.7 Timber Accounting

Of the three projects, only Berry Timber included removal of sawtimber. Board feet of timber harvested is converted to metric tons of carbon according to Smith *et al.* (2006), that provides a factor of 0.44 per thousand board feet to convert softwood lumber to metric tons of carbon. The fraction of carbon in primary wood products remaining over time in end uses and stored in land fill, as described in Smith *et al.* (2006), are then applied: after 10 years, 42.4% of carbon will remain in use as long-term wood products, and 11.6% will be sequestered in landfills; after 60 years, 17.3% of carbon will remain in long-term wood products, and 21.8% in landfills; after 100 years, 11.2% will remain in wood products and 24.3% in landfills.

rather than natural gas leads to an increase in CO_2 in the atmosphere because natural gas burns more cleanly than biomass. If coal were displaced instead of natural gas the savings would be greater while if the displacement is of electricity generated by nuclear power, solar, wind or hydro power then the result is an emission with no net saving.

If the stand is not treated the fuels are available in the forest to be emitted to the atmosphere through wildfires. However, this should not be considered under the biomass energy calculations. If it is then we are double-counting. The baseline fire risk multiplied by the stock gives the baseline emission from wildfires, which is the emission from fuels in the absence of fuel treatment.

2.2.8 Net Impact Calculations

Net project benefits following a treatment must incorporate

- carbon stocks in the forest;
- carbon emissions in a wildfire, accounting for the probability of fire;
- growth;
- carbon stored as long-term wood products;
- emissions offset through energy production.

The net emissions or removals in year one are calculated as

$$[(Ct + Cw + Ce - Cb)*(1 - risk)] + [(Ctf + Cw + Ce - Cbf)*(risk)]$$

Where	
Ct	carbon stocks remaining in the forest after treatment and without a wildfire
Cw	carbon stored as wood products
Ce	reduced emissions from using biomass for energy generation
Cb	carbon stocks in the forest before treatment and without a wildfire
risk	probability of fire
Ctf	carbon stocks remaining in the forest after treatment and with a wildfire
Cbf	carbon stocks remaining in the forest before treatment and with a wildfire

This equation states that the net emissions in year 1 are equal to:

The high probability that there will **be no fire** multiplied by the difference between stored carbon before and after treatment

Plus

The low probability that there will **be a fire** multiplied by the difference in total carbon storage after a fire in the treated stand and in the baseline stand.

3.0 Project Results

3.1 Berry Timber Results

3.1.1 Field results

Prior to treatment, the Berry Timber project had a stock of 70.1 tons of carbon per acre across all pools. Following the treatment, the average carbon stock was 49.4 t C/ac. Treatment therefore resulted in a decrease in carbon stocks of 20.7 tons per acre, 30% of pretreatment stocks. The breakdown by pool is shown in Table 2, and the confidence limits at a 90% confidence interval for the aboveground live carbon pool are shown in Table 2a.

Table 2. Berry Timber carbon stocks (metric t C/ac) before and after fuels treatments

Carbon pool	Pre-treatment	Post-treatment	Difference
Trees	39.7	27.1	-12.6
Roots	10.6	7.6	-3.0
TOTAL TREES	50.3	34.7	-15.6
Standing dead	0.5	0.3	-0.2
Down dead wood	12.0	9.3	-2.7
TOTAL DEAD	12.5	9.6	-2.9
WOOD			
Forest Floor	7.2	4.6	-2.6
Shrubs/herbaceous	0.2	0.4	0.2
TOTAL	70.1	49.4	-20.7

Table 2a. Upper and lower confidence limits at 90% CI for Berry Timber aboveground live carbon stocks (metric t C/ac) before and after fuels treatments

Aboveground	Pre-	Post-
live carbon	treatment	treatment
LCL	32.3	20.4
mean	39.7	27.1
UCL	47.1	33.8
CI as a % of		
mean	18.6 %	24.7 %

3.1.2 Potential fire emissions

Using FCCS-created fuel beds, a wildfire in the untreated stands would yield 46.6 tons of CO_2 per acre of emissions, while a wildfire in the treated stands would yield 31.7 t CO_2 / ac (Table 3). Using the FVS Fire and Fuels Extension, a wildfire in the untreated stands would yield 42.5 t CO_2 / ac of emissions, while a wildfire in the treated stands would yield 26.4 t CO_2 / ac (Table 4).

Table 3. FCCS fire modeling results for Berry Timber

	Prescribed Fire		Wi	ldfire
	Pre-treatment	Post-treatment	Pre-treatment	Post-treatment
Flame Length (ft)	2.5	2.2	6.1	5.0
Crown Fire Potential (scaled				
index 0-9)	3.6	2.3	4.2	3.0
Rate of Spread (ft/min)	3.6	4.5	18.3	19.4
CO ₂ emissions (t/ac)				
Canopy	-4.6	-1.8	-14.3	-6.2
Dead Wood	-22.4	-18.2	-28.2	-23.1
Litter	-2.9	-1.8	-3.5	-2.2
Total	-29.9	-21.8	-46.0	-31.5

Table 4. FVS fire modeling results for Berry Timber

	Wildfire			
	Pre-treatment	Post-treatment		
Flame Length (ft)	6.5	5.7		
Crowning index (miles/hr) ⁶	31.4	49.8		
CO ₂ emissions (t/ac)	-42.5	-26.4		
Total stand carbon				
remaining	58.1	42.4		

3.1.3 Timber and biomass

The commercial harvest on Berry Timber yielded 4,096 board feet of timber per acre. According to the conversion factor in Smith *et al.* (2006), this equals 1.8 t C/ac. Based on carbon disposition rates, a total of 1.0 t/ac will remain stored in either long-term wood products or landfill after 10 years; 0.7 t/ac will remain stored in either long-term wood products or landfill after 60 years; and 0.6 t/ac will remain stored in either long-term wood products or landfill after 100 years.

Wheelabrator received 3.3 bone dry tons of biomass per acre from the Berry Timber project, which represents 1.7 t C/ac. Because this biomass was used to generate energy, it offset 1.7 t C/ac * 27.2% = 0.5 t C/ac, resulting in reduced total emissions of 4.5 t CO_2 -e/ac (1.2 t C/ac).

3.1.4 Growth modeling

Based on FVS modeling (Table 5), in the absence of fire, the treatment resulted in an initial decrease in carbon stocks of 20.7 t C/ac (compare columns 1 and 2), and a reduced increase in carbon stocks of 11.7

⁶ The 20-foot windspeed required to cause an active crown fire.

t C/ac after 60 years, for a total decrease in live stocks of 32.4 t C/ac over a 60 year period relative to no treatment.

In the event of a wildfire in year zero, the treated stands contain 15.7 t C/ac less than the untreated stands (difference between columns 3 and 4), but carbon stocks in the treated stands increase more than those in untreated stands over 60 years (25.5 t C/ac), for a total increase of 9.8 t C/ac relative to the untreated stand.

Table 5. Modeled total stand carbon pre and post treatment and with and without fire on Berry Timber project. Modeling conducting using the Fuels and Fire Extension of FVS. Data in metric tons of carbon per acre

	Untreated,	Treated, no	Untreated,	Treated,
Year	no fire (1)	fire (2)	wildfire (3)	wildfire (4)
0	70.1	49.4	58.1	42.4
10	76.6	52.9	55.2	45.6
20	86.0	58.3	53.6	49.6
30	94.8	64.3	53.0	54.1
40	103.1	70.6	54.1	59.0
50	110.6	77.3	56.3	64.0
60	116.9	84.5	59.6	69.4
Total change	46.8	35.1	1.5	27
Total % change	167%	171%	103%	164%

FVS growth modeling (Table 6) indicates that after 60 years in the absence of wildfire, treated stands continue to have fewer trees per acre, lower basal area, and fewer cubic feet and board feet than untreated stands, while the quadratic mean diameter⁷ (QMD) is greater in the treated stands. However, the rate of change (Table 7) is greater in the treated stands for all measurements except QMD. This indicates that while the treated stands did not catch up to the untreated stands in absolute numbers, they had a lower mortality rate and a higher per tree growth rate overall. In addition, the trees remaining in the treated stands remained larger, on average, than those in the untreated stands.

In the event of a wildfire, treated stands have fewer trees per acre after 60 years, but increased basal area, QMD, cubic feet, and board feet, and they have a higher rate of change in all categories than do untreated stands.

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⁷ The diameter corresponding to the mean basal area of a stand.

Table 6. Projected Growth on Berry Timber project, modeled in FVS

	Untreated				Treated	
	Year 0	Year 60 – no fire	Year 60 - wildfire	0	Year 60 – no fire	Year 60 – wildfire
Trees per acre	282	160	73	132	118	64
Basal area	173	251	113	121	213	172
QMD	10.6	17.0	16.8	13.0	18.2	22.3
Cubic feet	4,873	8,799	3,828	3,541	7,383	6,270
Board feet	22,683	47,077	20,509	16,450	38,703	34,334

Table 7. Percent change within each scenario after 60 years of growth on Berry Timber project

	Untreated		Treated	
	No fire	Wildfire	No fire	Wildfire
Trees per acre	57%	26%	89%	48%
Basal area	145%	65%	176%	142%
QMD	160%	158%	140%	172%
Cubic feet	181%	79%	209%	177%
Board feet	208%	90%	235%	209%

3.1.5 Net GHG emissions/sequestration

Including carbon stored in long term wood products and energy offsets, for treated stands without wildfire, the total stock is 51.2 tons of carbon per acre and 44.2 t C/ac in the same stands following a wildfire. Figure 5 shows the tons of carbon per acre sequestered on Berry Timber in each of the four scenarios, the total carbon stored following treatment when wood products and biomass energy are included, and the percent change from untreated to treated and unburned to burned lands.

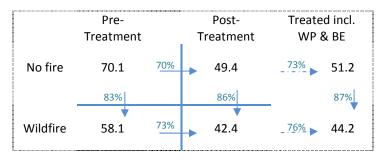


Figure 5. Tons of carbon per acre stored on Berry Timber project lands in each scenario, and included carbon stored in wood products and reduced emissions from biomass used to produce energy. Percentages show change from untreated lands to treated or from unburned to burned. BE = biomass energy. WP = storage in long term wood products and landfill after 5 years

Incorporating the risk of fire of 0.64% and utilizing the equation described above for net emissions or sequestration (section 2.2.6), [(Ct+Cw +Ce-Cb)*(1-risk)]+[(Ctf+Cw+Ce-Cbf)*(risk)], the fuels treatment on the Berry Timber project resulted in an effective immediate net carbon emission of 69.2 t CO_2 -e/ac (18.9 tons of carbon per acre).

In the absence of a wildfire, the fuels treatments and commercial harvest result in short term emissions of 83.2 t CO_2 /ac and emissions of 116.2 t CO_2 /ac over 60 years (Table 8).

Table 8. Net short and long term emissions from fuels treatment, without fire, on Berry Timber in tons of carbon dioxide per acre (+ = removals; - = emission)

	Short term 10 years	Long term 60 years
Biomass energy	-4.5	-4.5
Commercial timber	3.7	2.6
Treatment emissions	-86.9	-118.8
NET	-83.2	-116.2

For the treatment to yield benefits to the atmosphere, the emissions from treatments will need to be offset by reductions in emissions from a potential wildfire hitting the area. In order for the treatment to have an impact, such a fire would have to occur before fuels have returned to hazardous conditions, at which point it will be necessary to re-treat the forest. According to the FVS-modeled results, if a wildfire were to occur in the year of treatment, after 10 years the net emissions from treatment would be 36.0 t CO₂/ac.

3.2 Davis Results

3.2.1 Field results

Prior to treatment, the Davis project had a stock of 50.9 tons of carbon per acre across all pools. Following the treatment, the average carbon stock was 46.4 t C/ac. Treatment therefore resulted in a decrease in carbon stocks of 4.5 tons per acre, 8% of pretreatment stocks. The breakdown by pool is shown in Table 9, and the confidence limits at a 90% confidence interval for the aboveground live carbon pool are shown in Table 9a.

Table 9. Davis carbon stocks (metric t C/ac) before and after fuels treatments

Carbon pool	Pre-treatment	Post-	Difference
		treatment	
Trees	26.7	22.4	-4.3
Roots	7.8	6.3	-1.5
TOTAL TREES	34.5	28.7	-5.8
Standing dead	0.6	1.1	0.5
Down dead wood	9.0	11.1	2.1
TOTAL DEAD	9.6	12.2	2.6
WOOD			
Forest Floor	6.6	5.1	-1.5
Shrubs/herbaceous	0.2	0.4	0.2
TOTAL	50.9	46.4	-4.5

Table 9a. Upper and lower confidence limits at 90% CI for Davis above ground live carbon stocks (metric t C/ac) before and after fuels treatments

Aboveground live carbon	Pre- treatment	Post- treatment
LCL	22.0	18.1
mean	26.7	22.4
UCL	31.4	26.7
CI as a % of		
the mean	17.6 %	19.2 %

3.2.2 Potential fire emissions

Using FCCS-created fuel beds, a wildfire in the untreated stands would yield 35.2 tons of CO_2 per acre of emissions, while a wildfire in the treated stands would yield 39.2 tons of CO_2 per acre (Table 10). Using the FVS Fire and Fuels Extension, a wildfire in the untreated stands would yield 37.0 tons of CO_2 per acre of emissions, while a wildfire in the treated stands would yield 34.1 tons of CO_2 per acre (Table 11).

Table 10. FCCS fire modeling results for Davis

	Prescribed Fire		Wi	ldfire
	Pre-treatment	Post-treatment	Pre-treatment	Post-treatment
Flame Length (ft)	3.4	3.5	8.2	8.3
Crown Fire Potential (scaled				
index 0-9)	3.7	3.2	4.4	3.8
Rate of Spread (ft/min)	5.2	7.0	27.4	34.6
CO ₂ emissions (t/ac)				
Canopy	-2.4	-2.4	-7.5	-7.5
Dead Wood	-18.9	-22.2	-23.7	-28.2
Litter	-2.8	-2.6	-3.5	-3.1
Total	-24.1	-27.2	-34.7	-38.8

Table 11. FVS fire modeling results for Davis

	Wildfire		
	Pre-treatment	Post-treatment	
Flame Length (ft)	5.8	6.8	
Crowning index (miles/hr)8	25.1	36.8	
CO ₂ emissions (t/ac)	-37.0	-34.1	
Total stand carbon			
remaining	40.5	37.2	

3.2.3 Biomass

Wheelabrator received 11.4 bone dry tons of biomass per acre from the Davis project, which represents 5.7 tons of carbon per acre. Because this biomass was used to generate energy, it offset 5.7 t C/ac * 27.2% = 1.5 t C/ac, resulting in reduced total emissions of 15.4 t CO₂-e/ac (4.2 t C/ac).

3.2.4 Growth modeling

Based on FVS modeling (Table 12), in the absence of fire, the treatment resulted in an initial decrease in carbon stocks of 4.5 t C/ac (compare columns 1 and 2), and a reduced increase in carbon stocks of 7.7 t C/ac after 60 years, for a total decrease in live stocks of 12.2 t C/ac over a 60 year period relative to an untreated stand. In the event of a wildfire in year zero, the treated stands sequester 3.3 t C/ac less than the untreated stands (difference between columns 3 and 4), but carbon stocks in the treated stands

⁸ The 20-foot windspeed required to cause an active crown fire.

increase more than those in untreated stands over 60 years (3.6 t C/ac), for a total increase of 0.3 t C/ac relative to an untreated stand.

Table 12. Modeled total stand carbon pre and post treatment and with and without fire on Davis project. Modeling conducting using the Fuels and Fire Extension of FVS. Data in metric tons of carbon per acre

	Untreated,	Treated, no	Untreated,	Treated,
Year	no fire (1)	fire (2)	wildfire (3)	wildfire (4)
0	50.9	46.4	40.5	37.2
10	59.1	52.6	39.6	38.3
20	70.2	61.4	40.6	41.0
30	80.9	70.2	42.6	43.8
40	91.1	79.4	46.0	47.2
50	100.5	88.2	50.4	51.2
60	108.7	96.5	55.6	55.9
Total change	57.8	50.1	15.1	18.7
Total % change	214%	208%	137%	150%

FVS growth modeling (Table 13) indicates that after 60 years in the absence of wildfire, treated stands continue to have fewer trees per acre, lower basal area, and fewer cubic feet than untreated stands, while QMD is greater in the treated stands and the board feet is slightly higher.

Table 13. Projected Growth on Davis, modeled in FVS

	Untreated					
	Year 0	Year 60 – no fire	Year 60 - wildfire	0	Year 60 – no fire	Year 60 – wildfire
Trees per acre	405	205	98	164	128	46
Basal area	140	251	126	106	233	124
QMD	8.0	15.0	15.4	10.9	18.3	22.1
Cubic feet	3,141	8,246	4,181	2,730	8,072	4,612
Board feet	12,780	43,022	22,163	12,154	43,657	26,592

However, the rate of change (Table 14) is greater in the treated stands for all measurements except QMD. This indicates that while the treated stands did not catch up to the untreated stands in absolute numbers, they had a lower mortality rate and a higher growth rate overall. In addition, the trees remaining in the treated stands remained larger, on average, than those in the untreated stands.

In the event of a wildfire, treated stands have fewer trees per acre after 60 years and slightly lower basal area, but increased cubic feet, and board feet, and they have a higher rate of change in all categories than do untreated stands.

Table 14. Percent change after 60 years of growth on Davis project

	Untreated		Treated	
	No fire	Wildfire	No fire	Wildfire
Trees per acre	51%	24%	78%	28%
Basal area	179%	90%	220%	117%
QMD	188%	193%	168%	203%
Cubic feet	263%	133%	296%	169%
Board feet	337%	173%	359%	219%

3.2.5 Net GHG emissions/sequestration

Including carbon stored in long term wood products and energy offsets, treated stands without wildfirehave an estimated total stock of 47.9 tons of carbon per acre compared to a stock of 38.7 t C/ac in treated stands following a wildfire. Figure 6 shows the tons of carbon per acre sequestered on Davis in each of the four scenarios, the total carbon stored following treatment when wood products and biomass energy are included, and the percent change from untreated to treated and unburned to burned lands.

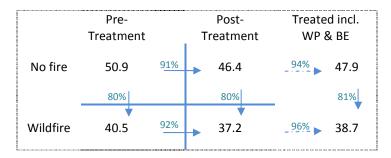


Figure 6. Tons of carbon per acre stored on Davis project lands in each scenario, and included carbon stored in wood products and reduced emissions from biomass used to produce energy. Percentages show change from untreated lands to treated or from unburned to burned.

Incorporating the risk of fire of 0.64% and utilizing the equation described above for net emissions or sequestration (section 2.2.6), [(Ct+Cw+Ce-Cb)*(1-risk)]+[(Ctf+Cw+Ce-Cbf)*(risk)], the fuels treatment on the Davis project resulted in a net carbon emission in year one of 11.0 t CO_2 -e/ac (3.0 t C/ac).

In the absence of a wildfire, the fuels treatments and commercial harvest result in short term emissions of 39.2 t CO_2 /ac and emissions of 60.1 t CO_2 /ac over 60 years (Table 15).

Table 15. Net short and long term emissions from fuels treatment, without fire, on Davis in tons of carbon dioxide per acre (+ = removals; - = emission)

	Short term 10 years	Long term 60 years
Biomass energy	-15.4	-15.4
Treatment emissions	-23.8	-44.7
NET	-39.2	-60.1

For the treatment to yield benefits to the atmosphere, the emissions from treatments will need to be offset by reductions in emissions from a potential wildfire hitting the area. In order for the treatment to have an impact, such a fire would have to occur before fuels have returned to hazardous conditions, at which point it will be necessary to re-treat the forest. According to the FVS-modeled results, if a wildfire were to occur in the year of treatment, after 10 years the net emissions from treatment would be 20.2 t CO₂/ac.

3.3 HH Biomass Results

3.3.1 Field results

Prior to treatment, the HH Biomass project had 63.9 tons of carbon per acre across all pools. Following the treatment, the average carbon stock was 52.5 t C/ac. Treatment therefore resulted in a decrease in carbon stocks of 11.4 tons per acre, 18% of pretreatment stocks. The breakdown by pool is shown in Table 16, and the confidence limits at a 90% confidence interval for the aboveground live carbon pool are shown in Table 16a.

Table 16. HH Biomass carbon stocks (metric t C/ac) before and after fuels treatments

Carbon pool	Pre-treatment	Post-treatment	Difference
Trees	36.5	27.3	-9.2
Roots	10.7	7.7	-3.0
TOTAL TREES	47.2	35.0	-12.2
Standing dead	0.9	0.2	-0.7
Down dead wood	9.0	11.1	2.1
TOTAL DEAD	9.9	11.3	1.4
WOOD			
Forest Floor	6.5	5.9	-0.6
Shrubs/herbaceous	0.2	0.3	0.1
TOTAL	63.9	52.5	-11.4

Table 16a. Upper and lower confidence limits at 90% CI for HH Biomass carbon stocks (metric t C/ac) before and after fuels treatments

Aboveground live carbon	Pre- treatment	Post- treatment
LCL	30.1	22.1
mean	36.5	27.3
UCL	42.9	32.5
CI as a % of		
the mean	17.5%	19.0%

3.3.2 Potential fire emissions

Using FCCS-created fuel beds, a wildfire in the untreated stands would yield 39.2 t CO_2 /ac of emissions, while a wildfire in the treated stands would yield 38.3 t CO_2 /ac (Table 17). Using the FVS Fire and Fuels Extension, a wildfire in the untreated stands would yield 39.6 tons per acre of emissions, while a wildfire in the treated stands would yield 35.2 tons per acre (Table 18).

Table 17. FCCS fire modeling results for HH Biomass

	Prescribed Fire		Wi	ldfire
	Pre-treatment	Post-treatment	Pre-treatment	Post-treatment
Flame Length (ft)	3.2	2.4	7.7	5.3
Crown Fire Potential (scaled				
index 0-9)	4.1	3.2	4.7	3.7
Rate of Spread (ft/min)	6.3	5.0	32.3	21.2
CO ₂ emissions (t/ac)				
Canopy	-3.7	-2.8	-11.0	-8.4
Dead Wood	-19.3	-20.7	-24.0	-26.6
Litter	-3.3	-2.9	-4.0	-3.5
Total	-26.3	-26.4	-39.0	-38.5

Table 18. FVS fire modeling results for HH Biomass

	Wildfire				
	Pre-treatment	Post-treatment			
Flame Length (ft)	4.9	6.6			
Crowning index (miles/hr)9	18.2	36.5			
CO ₂ emissions (t/ac)	-39.6	-35.2			
Total stand carbon					
remaining	52.7	42.8			

⁹ The 20-foot windspeed required to cause an active crown fire.

3.3.3 Biomass

Wheelabrator received 18.1 bone dry tons of biomass per acre from the HH Biomass project, which represents 9.0 tons of carbon per acre. Because this biomass was used to generate energy, it offset 9.0 t C/ac * 27.2% = 2.5 tC/ac, resulting in reduced total emissions of 23.8 t CO_2 -e/ac (6.5 t C/ac).

3.3.4 Growth modeling

Based on FVS modeling (Table 19), in the absence of fire, the treatment resulted in an initial decrease in carbon stocks of 11.4 t C/ac (compare columns 1 and 2), and a reduced increase in carbon stocks of 6.8 t C/ac after 60 years, for a total decrease in live stocks of 18.2 t C/ac over a 60 year period. In the event of a wildfire in year zero, the treated stands sequester 9.9 t C/ac less than the untreated stands (difference between columns 3 and 4), but carbon stocks in the treated stands increase more than those in untreated stands over 60 years (9.9 t C/ac), resulting in no net change in carbon sequestered after 60 years.

Table 20. Modeled total stand carbon pre and post treatment and with and without fire on HH Biomass project. Modeling conducted using the Fuels and Fire Extension of FVS. Data in metric tons of carbon per acre

Year	Untreated, no fire (10	Treated, no fire (2)	Untreated, wildfire (3)	Treated, wildfire (4)
0	63.9	52.5	52.7	42.8
10	75.4	59.1	49.7	44.9
20	88.9	68.5	49.5	48.9
30	100.0	77.7	51.7	52.8
40	108.2	86.1	55.7	57.5
50	114.6	94.1	615	62.7
60	119.9	101.7	68.3	68.3
Total change	56.0	49.2	15.6	25.5
Total % change	188%	194%	130%	160%

FVS growth modeling (Table 21) indicates that after 60 years in the absence of wildfire, treated stands continue to have fewer trees per acre, but the basal area is nearly the same, and they have greater cubic feet, board feet, and QMD than untreated stands.

Table 21. Projected Growth on HH Biomass, modeled in FVS

	Untreated					
	Year 0	Year 60 – no fire	Year 60 - wildfire	0	Year 60 – no fire	Year 60 – wildfire
Trees per acre	629	197	122	208	147	70
Basal area	197	251	156	132	247	166
QMD	7.6	15.3	15.3	10.8	17.6	20.8
Cubic feet	4,313	8,329	4,911	3,439	8,541	5,968
Board feet	16,521	42,748	24,613	14,849	45,528	33,357

The rate of change (Table 22) is greater in the treated stands for all measurements except QMD. This indicates that after 60 years, treated stands have a higher growth rate and have surpassed untreated stands in overall volume.

Table 22. Percent change after 60 years of growth on HH Biomass project

	Untreated		Treated	
	No fire	Wildfire	No fire	Wildfire
Trees per acre	31%	19%	71%	34%
Basal area	127%	79%	187%	126%
QMD	201%	201%	163%	193%
Cubic feet	193%	114%	248%	174%
Board feet	259%	149%	307%	225%

In the event of a wildfire, treated stands have fewer trees per acre after 60 years, but have higher basal area, and increased cubic feet and board feet, and they have a higher rate of change in all categories except QMD than do untreated stands.

3.3.5 Net GHG emissions/sequestration

Including carbon stored in long term wood products and energy offsets, treated stands without wildfire have a total of 55.0 tons of carbon per acre compared to a stock of 45.3 t C/ac in treated stands following a wildfire. Figure 7 shows the tons of carbon per acre sequestered on Davis in each of the four scenarios, the total carbon stored following treatment when wood products and biomass energy are included, and the percent change from untreated to treated and unburned to burned lands.

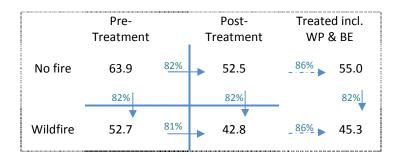


Figure 7. Tons of carbon per acre stored on HH Biomass project lands in each scenario, and included carbon stored in wood products and reduced emissions from biomass used to produce energy. Percentages show change from untreated lands to treated or from unburned to burned.

Incorporating the risk of fire of 0.64% and utilizing the equation described above for net emissions or sequestration (section 2.2.6), [(Ct+Cw +Ce-Cb)*(1-risk)]+[(Ctf+Cw+Ce-Cbf)*(risk)], the fuels treatment on the HH Biomass project resulted in a net carbon emission in year one of 32.3 t CO₂-e/ac (8.8 t C/ac).

In the absence of a wildfire, the fuels treatments and commercial harvest result in short term emissions of 83.6 t CO_2 /ac and emissions of 90.5 t CO_2 /ac over 60 years (Table 23).

Table 23. Net short and long term emissions from fuels treatment, without fire, on HH biomass in tons of carbon dioxide per acre (+ = removals; - = emission)

	Short term 10 years	Long term 60 years
Biomass energy	-23.8	-23.8
Treatment emissions	-59.8	-66.7
NET	-83.6	-90.5

For the treatment to yield benefits to the atmosphere, the emissions from treatments will need to be offset by reductions in emissions from a potential wildfire hitting the area. In order for the treatment to have an impact, such a fire would have to occur before fuels have returned to hazardous conditions, at which point it will be necessary to re-treat the forest. According to the FVS-modeled results, if a wildfire

were to occur in the year of treatment, after 10 years the net emissions from treatment would be 41.4 t CO_2/ac .

4.0 Discussion

In all three projects, the treatments resulted in significant net carbon emissions¹⁰. This result clearly has implications for the future potential of fuels treatments as a carbon projects offset category.

The reasons for the net emission from hazardous fuel reductions are multiple. In the case of the Davis and HH projects, deadwood stocks increased following the treatment. This may be due to these projects' focus on removal of pre-commercial trees and a corresponding increase in the amount of limbs and branches left following the treatment. Because the Berry project included sawtimber removal, the live standing carbon removed was far greater than for the other sites. However, due to milling inefficiencies and the retirement of wood over time, only a fraction of the carbon removed as sawtimber is stored in wood products over the long term. The use of biomass for electricity generation also does not compensate for the loss of carbon stored as standing timber, especially given the common use of natural gas and the minimum performance standards required in California.

Both the Berry and the HH treatments led to a decrease fire intensity and in potential CO₂ emissions from fire. There was a greater decrease on the Berry project, likely due to sawtimber removal and the subsequent reduction in the forest crown. Despite the decrease in emissions from fire, both projects continue to have lower standing carbon stocks after a fire in the year of treatment. The treatment on the Davis project led to increased fire intensity. According to FCCS modeling, the treated stand also yielded slightly higher CO₂ emissions from fire, while FVS modeling indicated slightly lower CO₂ emissions after a fire in the treated stand¹¹. The significant increase in both standing and lying deadwood on the Davis project explains the increase in fire intensity in the year following treatment. However, in subsequent years, as the deadwood continues to break down, the intensity of a potential fire is likely to decrease. In addition, the reduction in live ladder fuels improves the ability to control a fire.

The rate of growth on both Berry and HH increased following the treatment, but in the absence of a wildfire, total carbon stocks in the treated areas still had not surpassed those in untreated areas after 60 years. Growth rates on the Davis project were slightly lower following treatment. The treatment in the Davis project removed a smaller percentage of basal area than did the other two treatments, and may not have increased resources for residual trees enough to allow increased growth. However, when growth is projected following a fire in the year of treatment, all three projects experienced higher

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¹⁰ A complete accounting of emissions would have also incorporated equipment use. Though this project did not address equipment emissions, a similar project in Shasta County found emissions ranging from 0.8 to 1.8 tons CO₂/ac. While this is not an insignificant amount, it is a small fraction of the emissions which result from the removal of biomass from the forest.

¹¹ The difference between the two models is likely based on the specificity required of input data for each model. FCCS requires certain input data which is not required by FVS and which was not collected in the field. In order to run FCCS, base fuelbed data was used in cases where empirical data was not available.

growth rates with treatment. Treated stands in all three projects also have greater overall carbon stocks by year 30, though it's important to note that there is an annual risk of fire and subsequent wildfires were not modeled. Additionally, with each year following a hazardous fuels treatment, the benefits of the treatment are reduced and the maximum shelf life is probably less than 20 years.

Within the treated areas, all three projects had significant net emissions when considering treatment and the risk of a potential wildfire. Davis experienced the lowest emissions, but as discussed above, the treatment on Davis did not decrease fire intensity. If a fire were to occur in the year of treatment, all projects would still experience net emissions, though the impact of treatment emissions would be approximately halved in all cases.

One critical factor not addressed in this study is the impact of fuels treatment on fire intensity and emissions outside the treated area itself. In many cases, the reduced intensity of fire in a treated area decreases the intensity of fire in the surrounding untreated areas, increasing the beneficial aspects of the treatment without removing additional biomass. This is often referred to as a fire shadow. The size of a fire shadow along with the level of reduced emissions varies based on a number of factors, including topography, location of treatment, climatic conditions, and fire intensity. Incorporating the fire shadow in the overall emission calculations would decrease the net emissions in most cases, but given the extent of emissions for all three projects, it is likely that inclusion of a fire shadow would yield lower emissions but significant emissions would still result from treatment.

All three of the pilots led to a decrease in crown fire potential, which decreases fire severity and size. While treatments lead to net carbon emissions in both the short and long term in all three projects, there are, of course, additional benefits to fuels treatments, such as increased ability to successfully fight fires and decreased cost of fire fighting; reduced loss of life and property; and reduced potential damage to wildlife habitat.

These results are mirrored well in the results from the Alder Springs treatment in Mendocino National Forest conducted under funding from the US Forest Service. In Alder Springs, net emissions of 26.3 tons of carbon dioxide per acre were recorded immediately after treatment climbing to a total of 86.9 t CO₂-e/ac after 60 years.

The results from this study in combination with the paired study in Lake County and the allied study in Mendocino National Forest underlie the unsuitability of fuels treatment as a potential greenhouse gas offset generating activity. Instead we argue the shift should be made to policies minimizing greenhouse gas emissions from wildfires and from fuel treatments while minimizing wildfire risks to lives, homes and livelihoods in the WESTCARB region.

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Annex A: Standard Operating Procedures for Fuels Measurements in 2007

See separate attachment.



FINAL REPORT ON WESTCARB FUELS MANAGEMENT PILOT ACTIVITIES IN LAKE COUNTY, OREGON

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Winrock International

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Abstract

This report summarizes work by Winrock International, Lake County Resources Initiative (LCRI), and other Lake County, Oregon partners to implement hazardous fuel reduction/biomass energy pilot activities in WESTCARB Phase II (2006-10). Wildfire is a significant source of GHG emissions in Oregon and throughout the WESTCARB region. WESTCARB developed methodologies to evaluate, validate and demonstrate the potential of reducing hazardous fuel for biomass energy to contribute to GHG mitigation and adaptation. The report describes hazardous fuel reduction pilot activities on Federal and private lands in Lake County; pre- and post-treatment measurements to quantify forest carbon impacted by treatment and/or fire; analysis of data from these pilots to determine the net GHG impact of the fuel reduction treatments; and related work by LCRI to facilitate continued hazardous fuels reduction efforts in Lake County.

Keywords: Carbon, sequestration, hazardous fuel reduction, forest, Lake County

Executive Summary

Introduction

The West Coast Regional Carbon Sequestration Partnership (WESTCARB), led by the California Energy Commission, is one of seven US Department of Energy regional partnerships working to evaluate, validate and demonstrate ways to sequester carbon dioxide and reduce emissions of greenhouse gases linked to global warming.

Earlier analyses by Winrock showed wildland fire to be a substantial source of greenhouse gas (GHG) emissions throughout the region. Actions to reduce hazardous fuel loads, so as to reduce the probability, areal extent, or severity of wildfires, could result in lower net GHG emissions when compared to a baseline scenario without such treatments. Fuel reduction may also contribute to carbon sequestration by enhancing forest health or growth rates in post-treatment stands. Finally, for treatments where fuel removal to a biomass energy facility is feasible, additional GHG benefits may be created by substituting the biomass for fossil fuel rather than leaving the biomass in the forest to decompose.

Hazardous fuel reduction/biomass energy pilot activities were implemented in the two WESTCARB terrestrial pilot locations, Shasta County, California and Lake County, Oregon. These projects provide real-world data on carbon impacts of treatments, costs, and project-specific inputs to a related WESTCARB task, in which Winrock International and the WESTCARB Fire Panel are working to investigate whether the development of a rigorous methodology to estimate GHG benefits of activities to reduce emissions from wildland fires is feasible.

Purpose

This report provides results from the WESTCARB Phase II hazardous fuel reduction pilot activities in Lake County, Oregon. In addition we report on the revised 2010 Long-range Strategy for the Lakeview Federal Stewardship Unit, a related activity done in conjunction with the WESTCARB research efforts.

Project Objectives

The overall goal of WESTCARB Phase II is to demonstrate the region's key carbon sequestration opportunities through pilot projects, methodology development, reporting, and market validation. WESTCARB research will inform policymakers, communities, and businesses on how to invest in carbon capture and storage technology development and deployment to achieve climate change mitigation objectives.

The specific objectives of the Phase II Lake County fuel reduction pilots are to investigate the feasibility of fuels-treatment-based terrestrial sequestration by conducting pilot projects in a representative West Coast forest; compile information on site conditions, fuel treatment prescriptions, and costs; and inform and field-test the WESTCARB fire GHG emissions methodology. Fuels treatments were implemented on two project areas: Bull Stewardship and Collins-Hot Rocks.

Methodology for measuring impacts of hazardous fuels treatments

Pre- and post-treatment measurements were made on two fuels treatment projects in Lake County, Oregon. These projects involved removal of non-commercial biomass and sawtimber with the overall objective of reducing fuel loading and risk of catastrophic wildfire. The actual fuels treatments were not

initiated under WESTCARB support, but they provided an opportunity to conduct on-the-ground measurements of actual hazardous fuel reduction efforts.

The fuel reduction activities were located in the southwest corner of the county. One project area, Bull Stewardship, was on the Fremont-Winema National Forest, and the other, Collins-Hot Rocks, was on privately owned land.

A total of 38 plots were established in the Bull Stewardship and 22 in the Collins Companies Hot Rocks lands. Pre- and post-treatment measurements on these plots addressed live trees greater than 5 cm diameter at breast, canopy density, standing dead wood, understory vegetation, forest floor litter and duff, and lying dead wood. These represent the forest carbon pools that are likely to be affected by fire, treatment, or both, and so are critical to the accounting of hazardous fuel reduction treatment impacts and potential wildfire impacts on forest carbon.

These measurements were used to determine the carbon stocks before and after treatment and before and after a potential wildfire, for each project area. Growth modeling was conducted with the Forest Vegetation Simulator for both with and without treatment stands. Emissions from a potential fire were modeled in both with- and without-fuels treatment scenarios using both the Fuel Characteristic Classification System and the Forest Vegetation Simulator fire and Fuels Extension (FVS-FFE). FVS was also used to project growth on burned stands, incorporating the impacts of fire on the future stand.

Because it was not possible to send harvested biomass that did not go into sawtimber to a biomass energy plant and it was instead piled for burning, the CO_2 , CH_4 , and N_xO emissions from burning this biomass were calculated. Board feet of timber harvested was converted to metric tons of carbon, with retirement rates applied.

Project Outcomes

Bull Stewardship

Including carbon stored in long term wood products and emissions from pile burning, for treated stands without wildfire, a total of 73.2 tons of carbon per acre are stored, with 60.4 t C/ac still stored in the same stands following a wildfire.

Incorporating the risk of fire of 0.6% to calculate net emissions or removals (section 2.8), the fuels treatment on the Bull Stewardship project resulted in an effective immediate net emissions of 36.7 t CO_2 -e/ac (10.0 tons of carbon per acre).

In the absence of a wildfire, the fuels treatments and commercial harvest result in short term emissions of 59.4 t CO_2 /ac and emissions of 36.5 t CO_2 /ac over 60 years (table A1).

Table A1: Net short and long term emissions from fuels treatment without fire on Bull Stewardship in tons of carbon dioxide per acre (+ = removals; - = emission)

	Short term 10 years	Long term 60 years
Harvested timber	17.2	12.6
Treatment emissions	-68.2	-40.7
Pile burning emissions (CO₂e)	-8.4	-8.4
NET	-59.4	-36.5

For the treatment to yield benefits to the atmosphere, the emissions from treatments will need to be offset by reductions in emissions from a potential wildfire hitting the area. In order for the treatment to have an impact, such a fire would have to occur before fuels have returned to hazardous conditions, at which point it will be necessary to re-treat the forest. According to the FVS-modeled results, if a wildfire were to occur in the year of treatment, after 10 years the net emissions from treatment would be 40.7 t CO_2/ac .

Collins-Hot Rocks

Including carbon stored in long term wood products and emissions from pile burning, for treated stands without wildfire, a total of 34.1 tons of carbon per acre are stored, with 25.1 t C/ac still stored in the same stands following a wildfire.

Incorporating the risk of fire of 0.6% to calculate net emissions or removals (section 2.8), the fuels treatment on the Collins-Hot Rocks project resulted in an effective immediate net carbon emission of 76.3 t CO_2 -e/ac (20.8 tons of carbon per acre).

In the absence of a wildfire, the fuels treatments and commercial harvest result in short term emissions of 108 t CO_2 /ac and emissions of 113 t CO_2 /ac over 60 years (table A2).

Table A2: Net immediate and long term emissions from fuels treatment without fire on Collins-Hot Rocks in tons of carbon dioxide per acre (+ = removals; - = emission)

	Short term 10 years	Long term 60 years
Harvested timber	8.8	6.2
Treatment emissions	-101.9	-104.9
Pile burning emissions (CO ₂ e)	-17.6	-17.6
NET	-110.7	-116.3

For the treatment to yield benefits to the atmosphere, the emissions from treatments will need to be offset by reductions in emissions from a potential wildfire hitting the area. In order for the treatment to

have an impact, such a fire would have to occur before fuels have returned to hazardous conditions, at which point it will be necessary to retreat the forest.

According to the FVS-modeled results, if a wildfire were to occur in the year of treatment, after 10 years the net emissions from treatment would be $81.1 \text{ t CO}_2/\text{ac}$.

Related Efforts

The Lakeview Stewardship Group developed the 2005 Long-Range Strategy for the Lakeview Federal Stewardship Unit (Lakeview Stewardship Group 2005; see http://www.lcri.org/unit/longrange.htm) and the revised 2010 Long-range Strategy for the Lakeview Federal Stewardship Unit. In conjunction with the WESTCARB research efforts, the work of the Lakeview Stewardship Group have recently borne fruit in six important developments.

- After lengthy negotiations, a 20-year Interagency Biomass Supply MOU was signed on November 1, 2007. The purpose of the MOU is to provide a framework for planning and implementing forest and rangeland restoration and fuels reduction projects that address identified resource needs while being supportive of the Lakeview Biomass Project.
- The efforts of Lake County Resources Initiative (LCRI) and its Lake County partners have
 resulted in a commitment to the first 10-year Stewardship Contract in the US Forest Service
 Pacific Northwest Region. The contract, considered a model for the region, provides long-term
 supply of material necessary for the recent investments in a biomass power plant and small-log
 mill described below.
- Oregon Governor Kulongoski's office and biomass plant developer DG Energy jointly announced in January 2007 that DG Energy will construct a 13 MW biomass plant in Lakeview. This represented the culmination of multi-year efforts by all the partners in the Lakeview Stewardship Group to reach agreement around sustainable harvest levels and long-term biomass supply mechanisms necessary for investment in new capacity. Since collecting all the data from the stewardship contracts and other significant information from private lands it has been determined that a 25 MW biomass plant is sustainable. Currently the project is scheduled for a final decision on construction during summer 2010 and breaking ground in September 2010 with an estimated completion date of December 2012.
- Oregon Governor Kulongoski in March 2007 announced that the Collins Companies will expand
 their Fremont Sawmill operation in Lakeview by building a new \$6.8 million dollar small-log mill.
 The small-log mill is the direct result of the 20-year Interagency Biomass Supply MOU and 10year Stewardship Contract efforts spearheaded by LCRI, and provides an added tool for
 improving management of forests and hazardous fuels in Lake County.
- Considerable changes have occurred on Fremont-Winema National Forest since the beginning of the WESTCARB project in 2006. The original Forest Service prescriptions for Bull Stewardship, Burnt Willow and Kava are for much lighter treatments than treatments currently being implemented by the Forest Service. One of the critical outcomes is that there is infrastructure in place to restore the Forest Service lands to healthy conditions that will be able to better adapt to climate change.
- The national office of the Forest Service announced in February 2010 that they are accepting proposals for the Collaborative Forest Landscape Restoration Program (CFLRP). Region 6, which includes Lake County, sent in five proposals with the Lakeview Stewardship Group, with

Fremont-Winema proposal being the number one priority. Over 10 years this could mean an additional 20 million dollars above regular appropriations for fuels management and restoration in the 500,000 acre Lakeview Federal Stewardship Unit.

Conclusions and Recommendations

In both projects, the treatments resulted in overall carbon emissions. This result clearly has negative implications for the future potential of fuels treatments as a carbon projects offset category. Within the treated areas, both projects had significant net emissions when considering treatment and the risk of a potential wildfire. If a fire were to occur in the year of treatment, all projects would still experience net emissions, though the impact of treatment emissions would be slightly reduced.

Both pilots led to a projected decrease in crown fire potential, which decreases fire severity and size. While treatments lead to net carbon emissions in both the short and long term in all projects, there are, of course, additional benefits to fuels treatments, such as increased ability to successfully fight fires and decreased cost of fire fighting; reduced loss of life and property; and reduced potential damage to wildlife habitat.

The results from this study in combination with the paired study in Shasta County and the allied study in Mendocino National Forest underlie the unsuitability of fuels treatment as a potential greenhouse gas offset generating activity. Instead we argue the shift should be made to policies minimizing greenhouse gas emissions from wildfires and from fuel treatments while minimizing wildfire risks to lives, homes, wildlife habitat, and livelihoods in the WESTCARB region.

1.0 Introduction

1.1 Background and overview

The West Coast Regional Carbon Sequestration Partnership (WESTCARB), led by the California Energy Commission, is one of seven US Department of Energy regional partnerships working to evaluate, validate and demonstrate ways to sequester carbon dioxide and reduce emissions of greenhouse gases linked to global warming. Terrestrial (forestry and land use) sequestration options being investigated include afforestation, improved management of hazardous fuels to reduce GHG emissions from wildfires, biomass energy, and forest management. Shasta County, California and Lake County, Oregon were chosen for Phase II terrestrial sequestration pilot projects because of the diversity of land cover types present, opportunities to implement the most attractive terrestrial carbon activities identified in Phase I, and replication potential elsewhere in the WESTCARB region.

Earlier reports identified fire as a significant source of GHG emissions throughout the WESTCARB region. Average estimated emissions from fires for the 1990-96 analysis period were: 1.03 MMTCO₂e for Oregon (Pearson et al 2007a); 1.83 MMTCO₂e per year for California (Pearson et al 2009); 0.18 MMTCO₂e/yr for Washington (Pearson et al. 2007b); and 0.47 MMTCO₂e/yr for Arizona (Pearson et al. 2007c).

The estimated baseline GHG emissions helped focus attention in Phase II on the questions: can actions by landowners to manage forest fuel loads be shown to produce measurable GHG reductions by decreasing the risk, severity, or extent of catastrophic wildfires? If so, can scientifically rigorous methods for measuring, monitoring, and verifying these GHG reductions serve as the basis for new protocols and market transactions, ultimately allowing landowners who reduce hazardous fuels to receive "carbon credit" revenues and improving the cost-effectiveness of fuel reduction? To explore these questions, hazardous fuel reduction (and where possible, removal of fuel for biomass energy generation) was chosen as a WESTCARB Phase II pilot activity in Shasta and Lake counties, and the WESTCARB Fire Panel was formed to develop fire GHG methodologies and protocols as needed.

1.2 Project Objectives

The overall goal of WESTCARB Phase II is to validate and demonstrate the region's key carbon sequestration opportunities through pilot projects, methodology development, reporting, and market validation. WESTCARB research will inform policymakers, communities, and businesses on how to invest in carbon capture and storage technology development and deployment to achieve climate change mitigation objectives.

The specific objectives of the Phase II Lake County fuel reduction pilots are to:

- Verify the feasibility of fuels-treatment-based terrestrial sequestration by conducting pilot projects in a representative West Coast forest;
- Compile information on site conditions and fuel treatment prescriptions;
- Inform and field-test the WESTCARB fire GHG emissions methodology by:
 - Collecting measurements of real-world fuel treatments to quantify:
 - The carbon stocks available to be burned before and after treatment,
 - The direct impacts of fuel treatments on carbon stocks in different carbon pools (e.g. increases in dead wood, decreases in dense growth), and
 - The fuel removed from the forest for potential biomass energy applications;

- Providing input data for fire models used to simulate fire behavior and emissions in the baseline (without-treatment) and with-treatment scenarios.
- Promote continued hazardous fuels reduction efforts on Lake County forests and support the location of a biomass power plant in Lakeview through the work of the Lake County Resources Initiative including:
 - Serving as a liaison to the Lakeview Stewardship Group to assist in identifying the sustainable scale for the biomass power plant in Lakeview.
 - Serving as a liaison to secure a Memoranda of Understanding with U.S. Forest Service, Bureau of Land Management, and Oregon Department of Forestry stating a commitment to supply the biomass power plant.

1.3 Report Organization

The report is organized in four sections: project approach, results, related work and conclusions/ recommendations. Section 2 summarizes the private- and federal-lands fuel treatments chosen for study as WESTCARB pilot activities, and methods used for pre- and post-treatment measurements and data analysis. Section 3 provides results of those measurements and analyses. Section 4 details related work undertaken by the Lake County Resources Initiative regarding continued hazardous fuels treatments in Lake County. Section 5 discusses the findings and provides recommendations based on this research.

2.0 Project Approach

2.1 Fuel reduction project locations and descriptions

Pre- and post-treatment measurements were made on two fuels treatment projects in Lake County, Oregon. These projects involved removal of non-commercial biomass and sawtimber with the overall objective of reducing fuel loading and risk of catastrophic wildfire. Treatments also included chipping and removal of biomass fuel to a biomass energy plant. The actual fuels treatments were not initiated under WESTCARB support, but they provided an opportunity to conduct on-the-ground measurements of actual hazardous fuel reduction efforts.

The fuel reduction projects were located in the North Warner Mountains, northeast of Lakeview, Oregon. Figure 1 shows Lake County land ownership and forest classes. The fuel reduction activities were located in the southwest corner of the county.

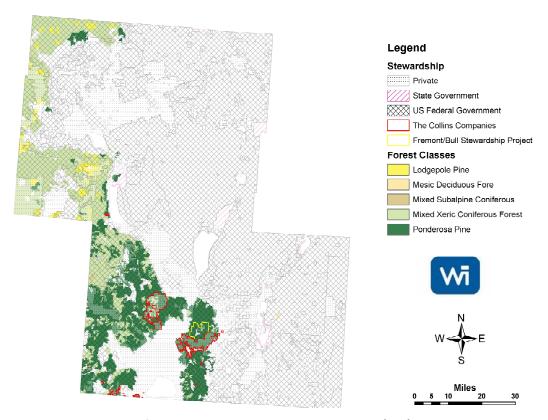


Figure 1. Lake County forest classes, Collins Companies lands (red) and Bull Stewardship Project boundary (yellow) adjacent to the eastern Collins Companies parcel.

The study on fuels treatments in Lake County was designed to examine the major ownership classes on forestlands in the county: Federal Government-owned National Forests and privately-owned industrial timberlands (Fig. 1 and 2):

- Federal lands Fremont-Winema National Forest
- Private industrial timberlands Collins Companies lands

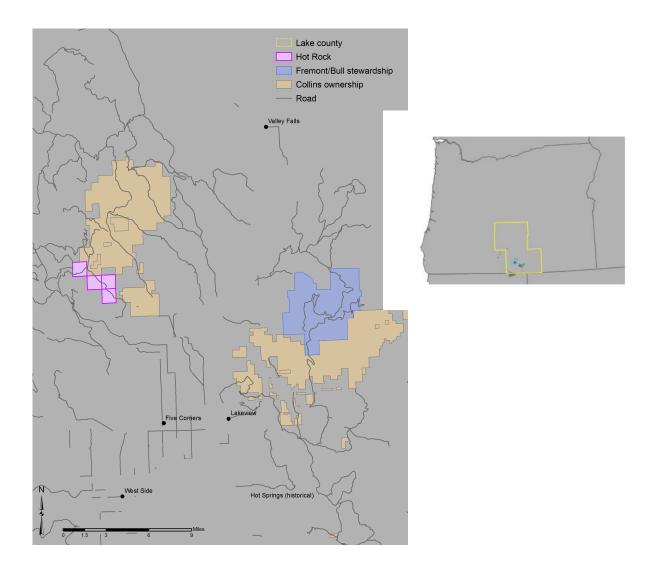


Figure 2. Lake County - US Forest Service Bull Stewardship Project (blue), and Collins Company Hot Rocks fuel treatments (pink).

2.1.1 Fuel reduction on Bull Stewardship Project lands

Location

The Bull Stewardship Project, on US Forest Service Fremont-Winema National Forest lands, was implemented by Collins Companies. The project is located approximately 9 miles northeast of the town of Lakeview, Oregon within the boundary of the Lakeview Federal Sustained Yield Unit in the Crooked Creek and Deep Creek Watersheds. The treatment area was 1,200 acres.

Treatment

Fuel reduction treatments began in July 2006, with pre-treatment measurements by Winrock/LCRI crews immediately preceding treatment. Treatments on Bull Stewardship were suspended in 2006 and began again in 2007. The treatments were ultimately completed in 2008. Stoppages were due to excessive fire risks.

The overall objective of the Bull Stewardship Project is forest health improvement and wildfire risk reduction, accomplished through a combination of commercial timber harvest and non-commercial biomass removals. Two types of treatment unit are included: timber harvest/stewardship and stocking level control. The treatment units within Bull Stewardship are shown in Figure 3.

On the timber harvest/stewardship units, the prescription calls for removal of commercial timber >9" diameter at breast height (DBH) (timber harvest component) and removal of non-merchantable material 7-8.9" DBH (stewardship component). The contractor has the option to remove non-merchantable material, including slash from commercial timber and whole non-commercial (<9") trees, for chipping and transport to a cogeneration facility.

On the stocking level control units, several different prescriptions exist, all requiring treatment of material 2 ft tall through 8.9" DBH inclusive. This material remains where it is cut, to reduce fuel loading (fuel ladders), but is not removed to a landing for further processing, and there is no commercial (>9") timber removal on these units. The objective is to favor Western White Pine and Ponderosa Pine. Specific prescriptions on the different stocking level control units include:

Treatment 1: Cut all coniferous live trees that are 2 feet tall through 8.9" DBH inclusive. Inclusive trees shall be cut within two drip lines of all western white pine or ponderosa pine 18"DBH or greater.

Treatment 2: Cut all coniferous live trees that are 2 feet tall through 8.9" DBH inclusive within two drip lines of all western white pine or ponderosa pine 11"DBH or greater.

Treatment 3: Cut all coniferous live trees that are 2 feet tall through 8.9" DBH inclusive within two drip lines of all ponderosa pine 18"DBH or greater.

Treatment 4: Cut all coniferous live trees that are 2 feet tall through 6.9"DBH inclusive. Inclusive trees and all white fir and lodgepole pine shall be cut within two drip lines of all western white pine or ponderosa pine 18"DBH or greater. Do not cut any western white pine or ponderosa pine within the two drip lines of another western white pine or ponderosa pine. Do not include white fir 18"DBH or greater in spacing calculations.

According to Forest Service records, 1.22 million cubic feet (1,002 cubic feet/acre) were harvested in the course of the treatment.

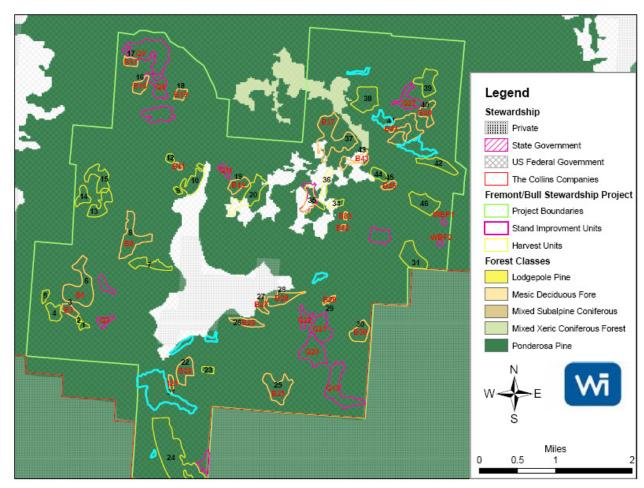


Figure 3. Treatment units on the Bull Stewardship Project. Treatments include commercial harvest units (yellow), stand improvement/stocking control units (pink), and combined timber harvest/stand improvement (blue).

2.1.2 Fuel reduction on Collins Companies lands

Location

Forest health/wildfire risk reduction projects on Collins Companies lands were included as WESTCARB pilots to evaluate approaches, costs and benefits of fuel reduction on private industrial timber lands. In 2007, Collins Companies began implementing fuels treatments on Collins lands in the Hot Rocks harvest units. See Figures 1 and 2 for overall Collins ownership boundaries in Lake County (red boundary), and Figure 4, showing the Hot Rocks harvest units. The total area treated was 288 acres.

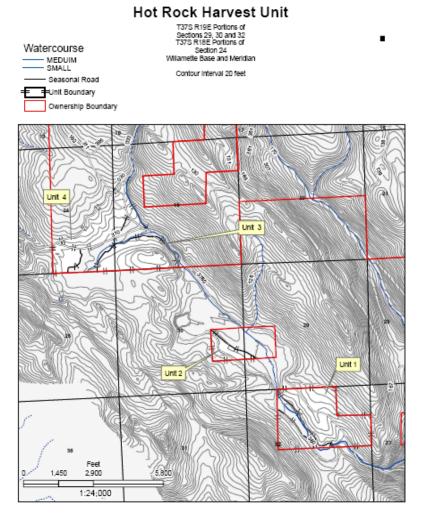


Figure 4. Hot Rocks harvest units, Collins Companies lands.

Treatment

Treatments were begun in June 2008 and completed in October 2008. The objectives of the Collins-Hot Rocks project was forest health improvement and wildfire risk reduction, accomplished through a combination of commercial timber harvest and non-commercial biomass removals. Treatments included selection harvest, commercial thinning, and variable retention harvest.

Selection harvest entails cutting trees greater than 8" dbh, with a post-harvest target of 80ft² basal area per acre and 160 trees per acre. Commercial thinning also targets a post-harvest basal area of 80ft²/ac, but the minimum cutting diameter is 3", and there are approximately 120 residual trees per acre. The variable retention post-harvest targets are 30 trees per acre and 20ft²/acre. In all three harvest systems, the focus is on choosing retention trees which are defect and disease free, possess phenotype superiority and a live crown ratio¹ greater than 50%. Some wildlife trees are also retained based on nesting potential.

¹ The ratio of tree crown length to total tree length.

The harvest removed 2,501 thousand board feet of sawtimber (8.7 thousand board feet /ac).

2.2 Pre- and post-treatment measurement methods

Field pre-treatment measurements² of Bull Stewardship and Collins-Hot Rocks fuels treatments were made in 2006 and 2007 and post-treatment measurement of both projects were made in 2008 and 2009.

2.2.1 Measurement Methods

The purpose of the measurements was to quantify the carbon stocks available to be burned before and after treatment, the direct impacts of fuel treatments on carbon stocks in different carbon pools (e.g. increases in dead wood, decreases in dense growth), and the fuel removed from the forest for biomass energy during treatment. Measurements also provided input data for fire models used to simulate fire behavior and emissions in the baseline (without-treatment) and with-treatment scenarios.

A total of 38 plots were established in the Bull Stewardship and 22 in the Collins Companies Hot Rocks lands.

Appropriate measurements of the following forest components were made at each plot:

- All trees >5 cm diameter at breast height, measured in nested plots and numbered for post-treatment measurements;
- Canopy density, measured at 36 points centered on the plot center;
- Standing dead wood;
- Understory vegetation, forest floor litter and duff, measured in clip plots and sub-sampled for dry weight determination;
- Lying dead wood, measured along transects, categorized by density class, and sub-sampled for density determination.

These represent the forest carbon pools that are likely to be affected by fire, treatment, or both, and so are critical to the accounting of hazardous fuel reduction treatment impacts and potential wildfire impacts on forest carbon. See Annex A for detailed Standard Operating Procedures followed in conducting pre- and post-treatment measurements of Lake County fuels treatments.

Plot locations were pre-assigned and random within units, taking into consideration elevation and species differences between units (higher elevation White Fir, higher elevation Lodgepole Pine, lower elevation White Fir/Ponderosa Pine). On navigation to each pre-assigned plot location, GPS coordinates were recorded and the plot center was marked using brightly painted rebar for ease of relocation post-treatment. Slope was noted for later analysis (plot-to-hectare expansion factor). All trees >5cm DBH were measured in a nested circular plot design, and numbered for post-treatment tally. Forest floor litter and duff was sampled in two 30 cm x 30 cm quadrats per measurement plot, and sub-samples collected for dry weight determination in a laboratory. The diameter of lying dead wood was measured along two 50 m line transects, categorized by density class, and sub-samples collected for density determination (dry weight per unit of green volume) and sent to a laboratory for drying. Post-treatment measurements were similar to pre-treatment as the objective is to examine the impact of treatments on

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² Field crews were made up of staff from Winrock and LCRI

forest carbon stocks. Trees were measured pre-treatment, and thus were only tallied to record removed/remaining post treatment. Forest floor litter and duff was re-measured in quadrats, and lying deadwood re-measured in line transects.

2.3 Fire modeling methods

Based on the field data disaggregated by carbon pool, emissions from a potential fire were modeled in both with- and without-fuels treatment scenarios. The modeling was conducted using two different approaches.

- 1. The FCCS program (Fuel Characteristic Classification System) was developed by the Pacific Northwest Research Station to capture the structural complexity and geographical diversity of fuel components across landscapes and to provide the ability to assess elements of human and natural change. FCCS is a software program that allows users to access a nation-wide library of fuelbeds or create customized fuelbeds. The fuelbeds are organized into six strata: canopy (trees), shrubs, nonwoody vegetation, woody fuels (lying deadwood and stumps), litter-lichen-moss, and ground fuels (duff and basal accumulations). FCCS calculates the relative fire hazard of each fuelbed, including crown fire, surface fire behavior, and available fuel potentials. It also reports carbon storage by fuelbed category and predicts the amount of combustible carbon in each category.³
- **2.** In addition to the FCCS modeling, fire effects were modeling using the **Forest Vegetation Simulator Fire and Fuels Extension** (FVS-FFE). FVS provides different outputs to FCCS and FVS can be used to project growth, incorporating the impacts of fire on the future stand.

The two models produced slightly different results, as they use different modeling methodologies and different biomass equations. They also produce somewhat different output. Reported outputs from FCCS include flame length in feet; crown fire potential as a scaled index from 0-9; rate of spread in feet per minute; and carbon consumed for live canopy, dead wood, and total. Reported results from FVS-FFE include flame length in feet; the crowning index in miles/hour; and total carbon consumed. Results for both prescribed fire and wildfire are reported from FCCS, while only wildfire is reported from the FVS-FFE results.

Although FVS uses a somewhat simpler methodology than FCCS for projecting fire impacts, it is based on established fire models and allows for growth projections. In order to address growth over time, FVS projections are used throughout the results, but FCCS output is presented to demonstrate the range of potential fire emissions.

2.4 Fire risk

Annual burn probability is difficult to project accurately as it is a factor of the likelihood of ignition and the conditions on the ground at the time of ignition, including fuels, climate, temperature, and topography (see Finney, 2005). WESTCARB research conducted by the Oregon Department of Forestry and the USDA Forest Service shows that the average overall conditional burn probability (probability that wildfire reaches a stand given one ignition source) in southeastern Oregon is 2.2% for untreated landscapes and 1.7% for the treated landscape, a 22.6% reduction in burn probability as a result of

³ More information is available at the FCCS website: http://www.fs.fed.us/pnw/fera/fccs/. The modeling was conducted by Dr. David "Sam" Sandberg – Emeritus of the PNW Research Station Fire and Environmental Application Team.

treatment (Jim Cathcart, 2010, Oregon Department of Forestry, pers. comm.). This is an overestimate of annual burn probability as it does not include the probability of an ignition. The mean fire return interval from 2001 to 2008 for dry-mesic mixed conifer forests in Lake County is 153 years (Eric Waller, 2010, UCB CFRO, pers. comm.). The inverse of this provides an annual burn probability of 0.6%. It is important to note that this is a generalized probability and is not based specifically on pre- and post-treatment conditions for these projects, but rather for Lake County as a whole.

2.5 Growth modeling

Stand growth, both with- and without-treatment and considering all pools, was modeled with the US Forest Service's Forest Vegetation Simulator (FVS), using the Inland California and Southern Cascades variant. The standard allometric equations in the Fire and Fuels Extension (FFE) of FVS were used to produce biomass and carbon reports in conjunction with forest growth. Data from both the pre- and post-treatment inventories were used, with the pre-treatment inventory year counted as year zero to compare with and without treatment scenarios. Growth was projected over a 60 year period, and did not include any additional future treatments. To incorporate the effects of wildfire on growth, FVS-FFE was also used to model wildfire behavior.

2.6 Modeled scenarios

For both fire and growth, four different scenarios were modeled for both projects. Each scenario includes the following carbon pools: above-ground live, below-ground live, standing dead, and lying dead. For the treated scenarios, carbon stored in merchantable timber after 100 years is included. To simplify calculations, the emissions arising from wood product conversion and subsequent retirement are included at the beginning of the project.

	Untreated	Treated
No Wildfire	1.Untreated, no fire	3.Treated, no fire
Wildfire	2.Untreated, wildfire	4.Treated, wildfire

- *Scenario 1* gives the situation where there is no treatment or fire. At time zero it represents simply the carbon stocks (tons of carbon per acre) prior to treatment.
- Scenario 2 is the carbon emissions and remaining stocks following a wildfire on untreated lands.
- Scenario 3 is the carbon stocks remaining after the treatment, incorporating any emissions that were a result of treatment activities but in the absence of any fire.
- Scenario 4 is the carbon emissions and remaining stocks following a wildfire on treated lands.

2.7 Harvested timber and biomass

Timber harvested is converted to metric tons of carbon according to Smith et al. (2006) that provides a factor of 7.48 thousand cubic feet and 0.44 thousand board feet per metric ton of carbon. The fraction of carbon in primary wood products remaining over time in end uses and stored in land fill, as described

in Smith et al. (2006), are then applied: after 10 years, 48.9% of carbon will remain in use as long-term wood products, and 12.5% will be sequestered in landfills; after 60 years, 20% of carbon will remain in long-term wood products, and 25.1% in landfills; after 100 years, 13% will remain in wood products and 27.9% in landfills.

While the intention for this project was to use harvested biomass for energy production, there have been setbacks in the development of a biomass energy plant in the area and thus no demand for such a product(see section 4.2). As a result, the harvested biomass has been piled and burned or piled awaiting the completion of a biomass power plant. For this reason, all harvested biomass that did not go into sawtimber is considered an emission as it will most likely be burned prior to completion of the plant. There are many forested areas in need of hazardous fuels reduction without access to a biomass facility, and so this method of accounting, while it leads to increased emissions, will be broadly applicable.

The burning of these piles leads to emissions of methane and nitrous oxide as well as carbon dioxide. The following emissions factors are recommended by the US EPA (Battye and Battye 2002):

Assuming a smoldering fire: CH₄⁴: 0.21 t CO₂-e/t burned

NO_x⁵: 0.34 t Co₂-e/t burned

2.8 Net impact calculations

Net project benefits following a treatment must incorporate

- carbon stocks in the forest;
- carbon emissions in a wildfire, accounting for the probability of fire;
- growth;
- carbon stored as long-term wood products;
- emissions from biomass harvested but not removed from the forest.

The net emissions or removals in year one are calculated as

$$[(Ct + Cw + Ce - Cb)*(1 - risk)] + [(Ctf + Cw + Ce - Cbf)*(risk)]$$

Where	
Ct	carbon stocks remaining in the forest after treatment and without a wildfire
Cw	carbon stored as wood products
Ce	reduced emissions from using biomass for energy generation
Cb	carbon stocks in the forest before treatment and without a wildfire
risk	probability of fire
Ctf	carbon stocks remaining in the forest after treatment and with a wildfire
Cbf	carbon stocks remaining in the forest before treatment and with a wildfire

⁵ Global warming potential of 310 used

⁴ Global warming potential of 21 used

This equation states that the net emissions in year 1 are equal to:

The high probability that there will <u>be no fire</u> multiplied by the difference between stored carbon before and after treatment

Plus

The low probability that there will <u>be a fire</u> multiplied by the difference in total carbon storage after a fire in the treated stand and in the baseline stand.

3.0 Project Outcomes

3.1 Bull Stewardship

3.1.1 Field results

Prior to treatment, the Bull Stewardship project had 81.6 tons of carbon per acre across all pools. Following the treatment, the average carbon stock was 66.3 t C/ac. Treatment therefore resulted in a decrease in carbon stocks of 15.3 tons per acre, 19% of pretreatment stocks. The breakdown by pool is shown in Table 1, and the confidence limits at a 90% confidence interval for the aboveground live carbon pool are shown in Table 1a.

Table 1: Bull Stewardship carbon stocks (metric t C/ac) before and after fuels treatments

Carbon pool	Pre-treatment	Post-treatment	Difference
Trees	48.2	35.0	-13.2
Roots	13.8	9.7	-4.1
TOTAL TREES	62.0	44.7	-17.3
Standing dead	1.2	0.8	-0.4
Down dead wood	14.4	10.5	-3.9
TOTAL DEAD WOOD	15.6	11.3	-3.7
Forest Floor	3.6	9.8	6.2
Shrubs/herbaceous	0.5	0.6	0.1
TOTAL	81.6	66.3	-15.3

Table 1a. Upper and lower confidence limits at 90% CI for Bull Stewardship aboveground live carbon stocks (metric t C/ac) before and after fuels treatments

Aboveground	Pre-	Post-
live carbon	treatment	treatment
LCL	43.5	30.3
mean	48.2	35.0
UCL	52.9	39.7
CI as a % of		
mean	9.7%	13.3 %

3.1.2 Potential fire emissions

Using FCCS-created fuel beds, a wildfire in the untreated stands would yield 52.8 tons of CO_2 per acre of emissions, while a wildfire in the treated stands would yield 42.0 t CO_2 /ac (Table 2). Using the FVS Fire and Fuels Extension, a wildfire in the untreated stands would yield 42.7 t CO_2 /ac of emissions, while a wildfire in the treated stands would yield 47.1 t CO_2 /ac (table 3).

The potential flame length and rate of spread are essentially the same following the treatment as they are before treatment. The crown fire potential is lower in the treated stands.

Table 2: FCCS fire modeling results for Bull Stewardship

	Prescribed Fire		Wi	ldfire
	Pre-treatment	Post-treatment	Pre-treatment	Post-treatment
Flame Length (ft)	3.2	3.2	7.6	7.5
Crown Fire Potential (scaled				
index 0-9)	3.9	3.8	4.7	3.5
Rate of Spread (ft/min)	5.7	6.0	27.5	29.5
CO ₂ emissions (t/ac)				
Canopy	-4.4	-5.1	-13.8	-15.4
Dead Wood	-28.2	-18.3	-36.3	-24.0
Litter	-2.4	-2.6	-2.8	-3.1
Total	-35.0	-26.0	-52.9	-42.5

Table 3: FVS fire modeling results for Bull Stewardship

	Wildfire		
	Pre-treatment	Post-treatment	
Flame Length (ft)	6.6	6.7	
Crowning index (miles/hr) ⁶	14.5	24.7	
CO ₂ emissions (t/ac)	-42.7	-47.1	
Total stand carbon remaining	69.5	53.5	

3.1.3 Timber and biomass

The harvest on Bull Stewardship yielded 1,020 ft³/ac. According to the conversion factor in Smith *et al.* (2006), this equals 7.6 t C/ac. Based on carbon disposition rates, a total of 4.7 t C/ac will remain stored in either long-term wood products or landfill after 10 years; 3.4 t C/ac will remain stored in either long-term wood products or landfill after 60 years; and 3.1 t C/ac will remain stored in either long-term wood products or landfill after 100 years.

Subtracting the removed sawtimber (7.6 t C/ac) from the total carbon removed in treatment (15.3 t C/ac), the remaining piled biomass represents 7.7 t C/ac or 15.4 tons of biomass per acre. This yields the following emissions (as described in section 2.7):

 CH_4 : 15.4 t burned * 0.21 t CO_2 -e/t burned = 3.2 t CO_2 e/ac

 NO_x : 15.4 t burned * 0.34 t Co_2 -e/t burned = 5.2 t CO_2 e/ac.

The total CH₄ and NO_x emissions from pile burning are 8.4 t CO₂e/ac.

3.1.4 Growth modeling

Based on FVS modeling (Table 4), in the absence of fire, the treatment resulted in an initial decrease in carbon stocks of 15.3 t C/ac (compare columns 1 and 2), but the treated stands had slightly higher growth than untreated stands (4.2 t C/ac), for a total decrease in live stocks of 11.1 t C/ac over a 60 year period relative to no treatment.

In the event of a wildfire in year zero, the treated stands contain 16.2 t C/ac less than the untreated stands (difference between columns 3 and 4 in Table 4). Over 60 years, carbon stocks in both treated and untreated stands decreased, but the decrease was somewhat less for treated stands. There was a total decrease in live stocks for treated stands of 6.8 t C/ac relative to untreated stands after 60 years.

⁶ The 20-foot windspeed required to cause an active crown fire.

Table 4. Modeled total stand carbon pre and post treatment and with and without fire on the Bull Stewardship project. Modeling conducted using the Fuels and Fire Extension of FVS. Data in metric tons of carbon per acre

	Untreated,	Treated, no	Untreated,	Treated,
Year	no fire (1)	fire (2)	wildfire (3)	wildfire (4)
0	81.6	66.3	69.7	53.5
10	84.9	66.3	60.0	46.5
20	86.1	68.7	52.2	41.6
30	86.6	70.5	47.5	38.4
40	86.6	72.6	44.5	36.4
50	86.5	74.3	42.3	35.1
60	86.5	75.4	40.9	34.1
Total change	4.9	9.1	-28.8	-19.4
Total % change	106%	114%	59%	64%

FVS growth modeling (Table 5) indicates that after 60 years in the absence of wildfire, treated stands continue to have fewer trees per acre, a lower basal area, lower quadratic mean diameter⁷ (QMD), and fewer cubic feet and board feet than untreated stands. However treated stands with wildfire have proportionally more and larger trees, higher basal area, and more merchantable timber than the original stand after 60 yr.

Table 5. Projected Growth on Bull Stewardship project, modeled in FVS

	Untreated				Treated	
	Year 0	Year 60 – no fire	Year 60 - wildfire	0	Year 60 – no fire	Year 60 – wildfire
Trees per	271	90	31	145	87	23
acre	2/1	30	31	143	07	25
Basal	214	200	63	143	176	53
area	217	200	0	175	170	3
QMD	12.1	20.2	19.3	13.4	19.3	20.6
Cubic	5,915	6,106	1,833	4,304	5,415	1,595
feet	3,313	0,100	1,055	4,304	3,413	1,353
Board	28,406	31,462	8,861	22,116	28,047	8,284
feet	20,400	31,402	0,001	22,110	20,047	0,204

However, the rate of change (Table 6) is greater in the treated stands for all measurements except QMD. This indicates that while the treated stands did not catch up to the untreated stands in absolute numbers, they had a lower mortality rate and a higher per tree growth rate overall. In addition, the trees remaining in the treated stands remained larger, on average, than those in the untreated stands.

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⁷ The diameter corresponding to the mean basal area of a stand.

In the event of a wildfire, treated stands have fewer trees per acre, and lower basal area, cubic feet and board feet after 60 years, but they have a higher rate of change in all categories except QMD than do untreated stands.

Table 6 Percent change after 60 years of growth on Bull Stewardship project

	Untre	eated	Trea	ated	
	No fire	Wildfire	No fire	Wildfire	
Trees per	33%	11%	60%	16%	
acre	55/0	11/0	0070	1070	
Basal	93%	29%	123%	37%	
area	9370	23/0	123/0	37/0	
QMD	167%	160%	144%	154%	
Cubic	104%	31%	126%	37%	
feet	10470	31/0	120/0	37/0	
Board	111%	31%	127%	37%	
feet	111/0	31/0	14/70	3/%	

3.1.5 Net GHG emissions/sequestration

Including carbon stored in long term wood products and emissions from pile burning, for treated stands without wildfire, a total of 71.6 tons of carbon per acre are sequestered with 58.8 t C/ac still sequestered in the same stands following a wildfire. Figure 5 shows the tons of carbon per acre sequestered on Bull Stewardship in each of the four scenarios, the total carbon stored following treatment when wood products and biomass energy are included, and the percent change from untreated to treated and unburned to burned lands.

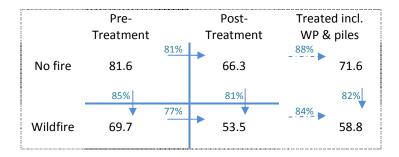


Figure 5: Tons of carbon per acre stored on Bull Stewardship project lands in each scenario, and including carbon stored in wood products and emissions from pile burning. Percentages show change from untreated lands to treated or from unburned to burned. WP = storage in long term wood products

Incorporating the risk of fire of 0.6%, and utilizing the equation described above for net emissions or sequestration (section 2.8), [(Ct+Cw +Ce-Cb)*(1-risk)]+[(Ctf+Cw+Ce-Cbf)*(risk)], the fuels treatment on the Bull Stewardship project resulted in an effective immediate net emissions of 36.7 t CO_2 -e/ac (10.0 tons of carbon per acre).

In the absence of a wildfire, the fuels treatments and commercial harvest result in short term emissions of $59.4 \text{ t CO}_2/\text{ac}$ and emissions of $36.5 \text{ t CO}_2/\text{ac}$ over 60 years (table 7).

Table 7: Net short and long term emissions from fuels treatment, without fire, on Bull Stewardship in tons of carbon dioxide per acre (+ = removals; - = emission)

	Short term 10 years	Long term 60 years
Harvested timber	17.2	12.6
Treatment emissions	-68.2	-40.7
Pile burning emissions (CO₂e)	-8.4	-8.4
NET	-59.4	-36.5

For the treatment to yield benefits to the atmosphere, the emissions from treatments will need to be offset by reductions in emissions from a potential wildfire hitting the area. In order for the treatment to have an impact, such a fire would have to occur before fuels have returned to hazardous conditions, at which point it will be necessary to re-treat the forest. According to the FVS-modeled results, if a wildfire were to occur in the year of treatment, after 10 years the net emissions from treatment would be 40.7 t CO_2/ac . Therefore, the treatment leads to net emissions with or without fire, but total emissions are somewhat lower in the event of a wildfire.

3.2 Collins – Hot Rocks

3.2.1 Field results

Prior to treatment, the Collins-Hot Rocks project had 54.9 tons of carbon per acre across all pools. Following the treatment, the average carbon stock was 35.0 t C/ac. Treatment therefore resulted in a decrease in carbon stocks of 19.9 tons per acre, 36% of pretreatment stocks. The breakdown by pool is shown in Table 8 and the confidence limits at a 90% confidence interval for the aboveground live carbon pool are shown in Table 8a.

Table 8: Collins-Hot Rocks carbon stocks (metric t C/ac) before and after fuels treatments

Carbon pool	Pre-treatment	reatment Post-treatment	
Trees	35.4	13.9	-21.5
Roots	9.8	4.0	-5.8
TOTAL TREES	45.2	17.9	-27.3
Standing dead	1.1	0.5	-0.6
Down dead wood	3.2	12.1	8.9
TOTAL DEAD	4.3 12.6		8.3
WOOD			
Forest Floor	4.9	4.1	0.5
Shrubs/herbaceous	0.5	0.5	0.0
TOTAL	54.9	35.0	-19.9

Table 8a. Upper and lower confidence limits at 90% CI for Collins-Hot Rocks aboveground live carbon stocks (metric t C/ac) before and after fuels treatments

Aboveground live carbon	Pre- treatment	Post- treatment
LCL	27.4	10.9
mean	35.4	13.9
UCL	43.4	17.0
CI as a % of		
mean	22.6 %	22.1 %

3.2.2 Potential fire emissions

Using FCCS-created fuel beds, a wildfire in the untreated stands would yield 26.8 tons of CO_2 per acre of emissions, while a wildfire in the treated stands would yield 48.6 t CO_2 /ac (Table 9). Using the FVS Fire and Fuels Extension, a wildfire in the untreated stands would yield 28.6 t CO_2 /ac of emissions, while a wildfire in the treated stands would yield 33.1 t CO_2 /ac (Table 10).

The potential flame length and rate of spread are substantially greater following the treatment that it is before treatment. The crown fire potential however is lower in the treated stands. This may indicate that the treatment increased deadwood, leading to a low and fast-moving fire, but reduced the potential for the fire to reach the crown.

Table 9: FCCS fire modeling results for Collins-Hot Rocks

	Prescribed Fire		Wi	ldfire
	Pre-treatment	Post-treatment	Pre-treatment	Post-treatment
Flame Length (ft)	2.0	3.6	4.5	8.5
Crown Fire Potential (scaled				
index 0-9)	3.3	2.1	4.0	3.2
Rate of Spread (ft/min)	3.1	4.8	13.3	24.0
CO ₂ emissions (t/ac)				
Canopy	-3.5	-2.6	-10.8	-7.7
Dead Wood	-10.5	-30.4	-13.0	-38.5
Litter	-2.4	-1.3	-2.8	-1.7
Total	-16.4	-34.3	-26.6	-47.9

Table 10: FVS fire modeling results for Collins-Hot Rocks

	Wildfire		
	Pre-treatment	Post-treatment	
Flame Length (ft)	3.8	8.2	
Crowning index (miles/hr) ⁸	11.6	20.6	
CO ₂ emissions (t/ac)	-28.6	-33.1	
Total stand carbon			
remaining	46.7	26.0	

⁸ The 20-foot windspeed required to cause an active crown fire.

3.2.3 Timber and biomass

The harvest on Hot Rocks yielded 8.7 mbf/ac⁹. According to the conversion factor in Smith et al. (2006), this equals 3.9 t C/ac. Based on carbon disposition rates, a total of 2.4 t C/ac will remain stored in either long-term wood products or landfill after 10 years; 1.7 t C/ac will remain stored in either long-term wood products or landfill after 60 years; and 1.6 t C/ac will remain stored in either long-term wood products or landfill after 100 years.

Subtracting the removed sawtimber (3.9 t C/ac) from the total carbon removed in treatment (19.9 t C/ac), the remaining piled biomass represents 16.0 t C/ac or 32.0 tons of biomass per acre. This yields the following emissions (as described in section 2.7):

 CH_4 : 32.0 t burned * 0.21 t CO_2 -e/t burned = 6.7 t CO_2 e/ac

 NO_x : 32.0 t burned * 0.34 t Co_2 -e/t burned = 10.9 t CO_2 e/ac.

The total CH_4 and NO_x emissions from pile burning are 17.6 t CO_2e/ac .

3.2.4 Growth modeling

Based on FVS modeling (Table 11), in the absence of fire, the treatment resulted in an initial decrease in carbon stocks of 19.9 t C/ac (compare columns 1 and 2), and a reduced increase in carbon stocks of 8.7 t C/ac after 60 years, for a total decrease in live stocks of 28.6 t C/ac over a 60 year period relative to no treatment.

In the event of a wildfire in year zero, the treated stands contain 20.7 t C/ac less than the untreated stands (difference between columns 3 and 4). Over 60 years, carbon stocks in both treated and untreated stands decreased, but the decrease was slightly less for treated stands. There was a total decrease in live stocks for treated stands of 17.9 t C/ac relative to untreated stands after 60 years.

Table 11: Modeled total stand carbon pre and post treatment and with and without fire on the Collins-Hot Rocks project. Modeling used the Fuels and Fire Extension of FVS. Results in metric tons of carbon per acre

	Untreated,	Treated, no	Untreated,	Treated,
Year	no fire (1)	fire (2)	wildfire (3)	wildfire (4)
0	54.9	35.0	46.7	26.0
10	61.7	33.9	39.9	20.9
20	69.0	37.3	36.0	18.6
30	73.4	41.3	34.6	17.8
40	76.8	45.6	34.6	17.8
50	79.5	49.5	35.6	18.4
60	81.8	53.2	37.1	19.2
Total change	26.9	18.2	-9.6	-6.8
Total % change	149%	152%	79%	74%

⁹ Harvest data was reported in cubic feet by the Forest Service for the Bull Stewardship project and in board feet by the Collins Company for the Hot Rocks project.

FVS growth modeling (Table 12) indicates that after 60 years in the absence of wildfire, treated stands continue to have fewer trees per acre, lower basal area, and fewer cubic feet and board feet than untreated stands while the QMD is greater in the treated stands.

Table 12 Projected Growth on Collins-Hot Rocks project, modeled in FVS

	Untreated		Treated			
	Year 0	Year 60 – no fire	Year 60 - wildfire	0	Year 60 – no fire	Year 60 – wildfire
Trees per	480	156	70	159	119	30
acre	400	150	70	133	113	30
Basal	198	210	87	77	158	43
area	130	210	σ,	,,	150	13
QMD	8.7	15.7	15.1	9.4	15.6	16.2
Cubic	4,215	6,149	2,349	1,567	4,341	1,139
feet	4,213	0,149	2,349	1,307	4,341	1,139
Board	13,887	28,639	10,139	5,168	19,151	5,135
feet	15,007	20,033	10,133	3,100	19,191	3,133

However, the rate of change (Table 13) is greater in the treated stands for all measurements except QMD. This indicates that while the treated stands did not catch up to the untreated stands in absolute numbers, they had a lower mortality rate and a higher per tree growth rate overall. In addition, the trees remaining in the treated stands remained larger, on average, than those in the untreated stands.

Table 13 Percent change after 60 years of growth on Collins-Hot Rocks project

	Untreated		Treated	
	No fire	Wildfire	No fire	Wildfire
Trees per	33%	15%	75%	19%
acre	33/0			
Basal	106%	44%	205%	56%
area	10070			
QMD	180%	174%	166%	172%
Cubic	146%	56%	277%	73%
feet	140/0			
Board	206%	73%	371%	99%
feet	20070			

In the event of a wildfire, treated stands have fewer trees per acre, and lower basal area, cubic feet and board feet after 60 years, but they have a higher rate of change in all categories except QMD than do untreated stands.

3.2.5 Net GHG emissions/sequestration

Including carbon stored in long term wood products and emissions from pile burning, for treated stands without wildfire, a total of 34.1 tons of carbon per acre are sequestered with 25.1 t C/ac still sequestered in the same stands following a wildfire. Figure 6 shows the tons of carbon per acre sequestered on Bull Stewardship in each of the four scenarios, the total carbon stored following treatment when wood products and biomass energy are included, and the percent change from untreated to treated and unburned to burned lands.

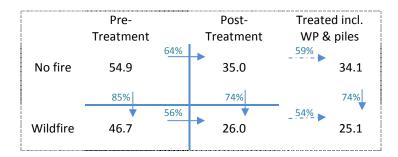


Figure 6: Tons of carbon per acre stored on Collins-Hot Rocks lands in each scenario, and including carbon stored in wood products and emissions from pile burning. Percentages show change from untreated lands to treated or from unburned to burned. WP = storage in long term wood products

Incorporating the risk of fire of 0.6%, and utilizing the equation described above for net emissions or sequestration (section 2.8), [(Ct+Cw +Ce-Cb)*(1-risk)]+[(Ctf+Cw+Ce-Cbf)*(risk)], the fuels treatment on the Collins-Hot Rocks project resulted in an effective immediate net carbon emission of 76.3 t CO_2 -e/ac (20.8 tons of carbon per acre).

In the absence of a wildfire, the fuels treatments and commercial harvest result in short term emissions of 111 t CO_2 /ac and emissions of 116 t CO_2 /ac over 60 years (table 14).

Table 14: Net short and long term emissions from fuels treatment without fire on Collins-Hot Rocks in tons of carbon dioxide per acre (+ = removals; - = emission)

	Short term 10 years	Long term 60 years
Harvested timber	8.8	6.2
Treatment emissions	-101.9	-104.9
Pile burning emissions (CO ₂ e)	-17.6	-17.6
NET	-110.7	-116.3

For the treatment to yield benefits to the atmosphere, the emissions from treatments will need to be offset by reductions in emissions from a potential wildfire hitting the area. In order for the treatment to have an impact, such a fire would have to occur before fuels have returned to hazardous conditions, at which point it will be necessary to retreat the forest. According to the FVS-modeled results, if a wildfire were to occur in the year of treatment, after 10 years the net emissions from treatment would be 81.1 t

 CO_2 /ac. Therefore, the treatment leads to net emissions with or without fire, but total emissions are lower in the event of a wildfire.

4.0 Related efforts

4.1.1 Lakeview Stewardship Group

The Lakeview Stewardship Group was formed in 1998-99, involving LCRI, the Collins Companies, Concerned Friends of the Fremont/Winema, Defenders of Wildlife, USDA Forest Service Fremont-Winema National Forest, Lake County Chamber of Commerce, Lakeview High School, Lakeview Ranger District, Oregon Department of Economic and Community Development, Paisley Ranger District, Sustainable Northwest, The Threshold Foundation, The Wilderness Society, and local citizens. These partners have been engaged in a long-term, consensus-based effort to articulate a strategy for sustainable forest management of the 495,000-acre Lakeview Federal Stewardship Unit (LFSU) in the Fremont-Winema National Forest. In the context of dramatically reduced timber harvest offerings, mill closures, economic decline and sometimes acrimonious industry vs. environment debates, the LSG has been working to develop collaborative management goals balancing the full range of economic, social and ecosystem values provided by the forest. A key output of this process was the 2005 Long-Range Strategy for the Lakeview Federal Stewardship Unit (Lakeview Stewardship Group 2005; see http://www.lcri.org/unit/longrange.htm) and the revised 2010 Long-range Strategy for the Lakeview Federal Stewardship Unit (see Annex B).

The LFSU long-term objectives are to "sustain and restore a healthy, diverse, and resilient forest ecosystem that can accommodate human and natural disturbances; sustain and restore the land's capacity to absorb, store, and distribute quality water; and provide opportunities for people to realize their material, spiritual, and recreational values and relationships with the forest." Integral to sustaining and restoring a healthy, diverse, and resilient forest ecosystem that can accommodate human and natural disturbances is the effort to improve management of wildfire on National Forest lands. Partners have focused on reaching agreement and developing new tools to reduce hazardous fuel loading and improve forest health. In relation to WESTCARB goals, the most important of these tools are: stewardship contracts, Memoranda of Understanding and other mechanisms for long-term biomass supply as the basis for investments in new capacity; installing new biomass energy and small log processing facilities in Lakeview, to promote cost-effective utilization of the full range of material removed from the forest to meet stewardship and fuel reduction goals; and exploring new ways to manage forest carbon, including developing the science and policy basis for transacting carbon credits from fuel reduction.

LSG efforts have recently borne fruit in six important developments, summarized below.

4.1.2 Twenty-year biomass supply MOU

After lengthy negotiations, a 20-year Interagency Biomass Supply MOU was signed on November 1, 2007. The parties to the MOU include Lake County Resources Initiative, Lake County, Town of Lakeview, City of Paisley, DG Energy LLC, DG Investors LLC, The Collins Companies, Oregon Department of Forestry, USDA Forest Service Fremont-Winema National Forest, and Bureau of Land Management- Lakeview District. The purpose of the MOU is to provide a framework for planning and implementing forest and rangeland restoration and fuels reduction projects that address identified resource needs while being supportive of the Lakeview Biomass Project. In the MOU, each of the parties offers specific

commitments relevant to fire risk reduction, forest health, biomass energy and a sustainable forest industry in the region. For the Forest Service, these include exploring new long-term supply mechanisms and offering at least 3,000 treatment acres per year within and another 3,000 acres per year outside the Lakeview Federal Stewardship Unit. BLM meanwhile commits to offer 2,000 treatment acres per year District-wide. LCRI's commitments include providing local coordination between the Collins Companies, Jeld-Wen and Forest Service on the WESTCARB project, with the goal of establishing a financing system for reducing uncharacteristically large fire events and provide additional revenues for restoration activities, and working with Iberdrola Renewables to support construction of an appropriately sized (25 MW) biomass plant in Lake County. The Oregon Department of Forestry's commitments include using SB1072 authorities to facilitate 10-year stewardship contracts, developing a cooperative state-wide MOU among state agencies, Forest Service and BLM bringing together elements of existing state programs under Energy, Economic and Community Development, Fish and Wildlife, and Forestry, and supporting the work of federal agencies to develop stewardship contracts and promote bioenergy.

The MOU was reviewed by Forest Service and BLM legal counsel and is in effect. The MOU signing was November 1, 2007, at a ceremony in Lakeview for the launch of the biomass plant and small-log sawmill. Undersecretary of Agriculture Mark Rey was in attendance along with many State dignitaries including two national environment group and two regional environmental groups. The text of the 20-year Interagency Biomass Supply MOU is included in Annex C.

4.1.3 Ten-year stewardship contract

The efforts of LCRI and its Lake County partners have resulted in a commitment to the first 10-year Stewardship Contract in the US Forest Service Pacific Northwest Region. The contract, considered a model for the region, provides long-term supply of material necessary for the recent investments in a biomass power plant and small log mill described below. The 10-year stewardship contract awarded to the Collins Companies on July 22, 2008 guarantees 3,000 acres of treatment per year and a total of \$100,000 of work over the 10-year period. Specific treatment prescriptions are planned on a two year cycle. The MOU states in addition to the 10-year stewardship contract in the Unit there will be two additional 10-year contracts, one on Forest Service lands outside the Unit and one on BLM lands. There contracts have not been pursued because of the current economic downturn.

4.1.4 Biomass Power Plant

Oregon Governor Kulongoski's office and biomass plant developer DG Energy jointly announced in January 2007 that DG Energy will construct a 13 MW biomass plant in Lakeview. This represented the culmination of multi-year efforts by all the partners in the Lakeview Stewardship Group to reach agreement around sustainable harvest levels and long-term biomass supply mechanisms necessary for investment in new capacity. In their initial efforts to locate a biomass plant in Lake County, LCRI received volume estimates for slash piles that ranged from 1 to 11 bone dry tons (BDT). It is impossible to appropriately size a biomass plant with this range. Using what information was available and a Coordinated Resource Offering Protocol by Mater Engineering it was decided it could sustain a 15 MW biomass plant. Since collecting all the data from the stewardship contracts and other significant information from private lands it has been determined that a 25 MW biomass plant is sustainable.

Marubeni Sustainable Energy subsequently bought the development rights from DG Energy in 2007. In 2009 Iberdrola Renewables purchased the development rights from Marubeni. As a result of new supply information the plant size has gone from a net 13MW to a net 24.9 MW and the investment went from \$20 million to over \$70 million. Currently the project is scheduled for a final decision on

construction this summer 2010 and breaking ground in September 2010 with an estimated completion date of December 2012. The project is designed to use biomass from overstocked forests, helping to reduce wildfires, improve forest health and create jobs. The Lakeview Biomass Project was designated an "Oregon Solutions" initiative by Governor Kulongoski, resulting in a collaborative process involving federal and state agencies, industry, and non-profit organizations to build consensus for the project and secure a sustainable supply of biomass.

The Governor's press release is at http://governor.oregon.gov/Gov/P2007/press 011007b.shtml and is included in Annex D. The Oregon Solutions Declaration of Cooperation is included in Annex E and a 2010 support letter from the Governor is in Annex F.

4.1.5 New small log mill in Lakeview

Oregon Governor Kulongoski in March 2007 announced that the Collins Companies will expand their Fremont Sawmill operation in Lakeview by building a new \$6.8 million dollar small log mill. The small log mill is the direct result of the 20-year Interagency Biomass Supply MOU and 10-year Stewardship Contract efforts spearheaded by LCRI, and provides an added tool for improving management of forests and hazardous fuels in Lake County. The combination of the existing Fremont Sawmill for processing larger logs, the new small-diameter log mill, and the new biomass energy plant will provide the tools necessary for cost-effective utilization of the full range of material removed from the forest to meet stewardship, forest health restoration, and wildfire risk reduction objectives. The biomass plant and small log mill, the result of an "Oregon Solutions" initiative involving nearly 70 public, private and community organizations, represent two sides of "an integrated solution to effective management of forest health and reducing fire danger in the Fremont National Forest. Both the biomass facility and the small log mill serve as models for collaboration between industry, conservationists and state government in enhancing forest health, developing renewable energy and creating jobs" (Governor Kulongoski's press release, March 7, 2007). The full text of the press release is included in **Annex D**.

A November 1, 2007 ceremony in Lakeview served as the ribbon-cutting for the new small-diameter sawmill and initial kickoff for the biomass energy plant, as well as the signing ceremony for the 20-year biomass supply MOU and announcement of the first 10-year stewardship contract offer by the Forest Service - Pacific Northwest Region.

In addition to the ecological outcomes, the economic outcomes are significant for a rural community. The sawmill and biomass plants are making an \$80 million dollar investment in a county that is 78% public ownership. These investments have resulted in retaining 85 sawmill jobs, and will create 18 jobs at the biomass plant and 50-75 jobs in the woods. An Oregon Business 2010 report estimates these investments will have an annual payroll of over \$18 million and will pay over \$1 million/year in income tax to the State of Oregon (see attached Business Oregon report, Annex G). South Central Oregon

Economic Development District estimates that local taxing districts such as the Town of Lakeview, Lake County, Library, Hospital, cemetery, school district, etc. will receive an estimated \$1.8 million yearly in taxes. Oregon has established what is called Empowerment Zones and companies locating in these zones can get up to 15 years property tax abatement. The Lakeview Biomass plant is in an Empowerment Zone where they will be paying a substantially less Community Service Fee in lieu of property tax for 15 years. The Biomass Impact

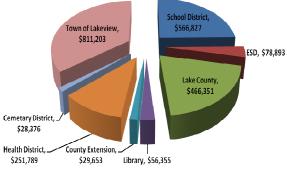


Figure 7: Distribution of increased tax revenue resulting from biomass facility in year 16 and beyond

to Taxing Districts graph (figure 7) is based on estimated taxes in year 16 and beyond.

4.1.6 Influence on hazardous fuels management

Considerable changes have occurred on Fremont-Winema National Forest since the beginning of this project in 2006. The original Forest Service prescriptions for Bull Stewardship, Burnt Willow and Kava were much lighter treatments than treatments currently being implemented by the Forest Service. In designing these projects, the Forest Service was cautious on their prescriptions as they were concerned about possible lawsuits. When the Lakeview Stewardship Group reviewed the completed treatments in these early stewardship projects they informed the Forest Service that treatments need to be heavier in order to reduce fuel loads enough to influence fire behavior and restore natural fire to the landscape. In addition, the Collins Companies invested in a new small diameter sawmill that took merchantable material from a 9" DBH to a 7" DDH, resulting in an increase in the volume of sawlogs taken off the forest. Another significant change that occurred during the project was the collapse of the economy in 2008 with lumber prices being so low that all sawmills were losing money. Because logging contractors can request an extension to carry out a prescription, this delayed the work until a time when the market returns to more favorable conditions.

The 20-year MOU and the Lakeview Stewardships Group's 2005 Long-range Strategy for the Lakeview Federal Stewardship Unit was significant enough that The Collins Companies invested \$6.8 million in a new sawmill rather than closing down the sawmill. The other significant changes during this time were that the Lakeview Stewardship Group informed the Forest Service they wanted the Forest Service to concentrate on commercial logging operations, and eliminate fire salvage logging. The sawmills viability hinged on getting approximately 20MBF off the Lakeview Federal Stewardship Unit. As a result of the 10-year Stewardship Contract Collins was awarded in 2008, the goal of 20 MBF was exceeded as shown in Figure 8. World market conditions have reduced the amount since 2008, and it will likely climb again with better market return. One of the critical outcomes is that the infrastructure is in place to restore the Forest Service lands to healthy conditions that will be able to adapt to climate change.

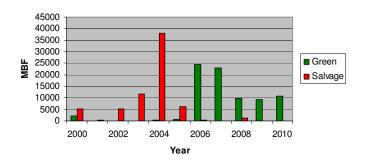


Figure 8: Board feet harvested in Lake County between 2000 and 2010 through either salvage logging or green harvests

4.1.7 Collaborative Forest Landscape Restoration Program (CFLRP)

The National office of the Forest Service announced in February 2010 that they are accepting proposals for the Collaborative Forest Landscape Restoration Program (CFLRP). Projects must be collaborative in nature, address at least a 30,000 acre landscape, and and include a strategic plan. The CFLRP stated that

up to 10 projects could be chosen this fiscal year and no more than two from any one region would be funded. Region 6 sent in 5 proposals with the Lakeview Stewardship Group Fremont-Winema proposal being the number 1 priority. Over 10 years this could mean an additional 20 million dollars above regular appropriations for fuels management and restoration in the 500,000 acre Lakeview Federal Stewardship Unit. As part of the CFLRP proposal the Lakeview Stewardship group revised their 2005 Long-range Strategy for the Lakeview Federal Stewardship Unit, see Annex H. Final CFLRP awardees will be notified by late summer.

5.0 Conclusions and Recommendations

In both projects, the treatments resulted in significant net carbon emissions¹⁰. This result clearly has implications for the future potential of fuels treatments as a carbon projects offset category.

The reasons for the net emission from hazardous fuel reductions are multiple. In the case of the Collins-Hot Rocks project, deadwood stocks increased following the treatment. This may be due to an increase in the amount of limbs and branches left following the treatment. Because the projects included sawtimber removal, the live standing carbon removed was substantial. However, due to milling inefficiencies and the retirement of wood products over time, only a fraction of the carbon removed as sawtimber is stored in wood products over the long term. Had it been possible to utilize biomass for energy production, some of the emissions may have been offset, but there would still be net emissions as a result of treatment. As it was, the piling and burning of biomass further contributed to overall emissions.

While the Bull Stewardship treatment led to a slight decrease in fire intensity, the Collin-Hot Rocks treatment led to an increase in fire intensity, and both led to an increase in potential emissions from a fire. Both treatments led to a substantial increase in large woody fuel loads and subsequent biomass consumption. If the woody fuels that resulted from the treatments been removed from the site, there likely would have been a decrease both in surface fire behavior and potential carbon release. Both treatments produced an apparent decrease in crown fire potential from future fires, which reduces the severity and size of wildfires, and improves the ability to control a fire.

The rate of growth increased slightly following the treatments, but in the absence of a wildfire, total carbon stocks in the treated areas still had not surpassed those in untreated areas after 60 years. Following a wildfire, carbon stocks continued to decline for both the treated and the untreated stands.

Within the treated areas, both projects had significant net emissions when considering treatment and the risk of a potential wildfire. If a fire were to occur in the year of treatment, all projects would still experience net emissions, though the impact of treatment emissions would be slightly reduced.

One critical factor not addressed in this study is the impact of fuels treatment on fire intensity and emissions outside the treated area itself. In many cases, the reduced intensity of fire in a treated area decreases the intensity of fire in the surrounding untreated areas, increasing the beneficial aspects of the treatment without removing additional biomass. This is often referred to as a fire shadow. The size of a fire shadow along with the level of reduced emissions varies based on a number of factors, including topography, location of treatment, climatic conditions, and fire intensity. Incorporating the fire shadow

 $^{^{10}}$ A complete accounting of emissions would have also incorporated equipment use. Though this project did not address equipment emissions, a similar project in Shasta County found emissions ranging from 0.8 to 1.8 tons CO_2 /ac. While this is not an insignificant amount, it is a small fraction of the emissions which result from the removal of biomass from the forest.

in the overall emission calculations would decrease the net emissions in most cases, but given the extent of emissions for both projects, it is likely that inclusion of a fire shadow would yield lower emissions but significant emissions would still result from treatment.

Both pilots led to a decrease in crown fire potential, which decreases fire severity and size. While treatments lead to net carbon emissions in both the short and long term in both projects, there are, of course, additional benefits to fuels treatments, such as increased ability to successfully fight fires and decreased cost of fire fighting; reduced loss of life and property; and reduced potential damage to wildlife habitat.

These results are mirrored well in the results from the Alder Springs treatment in Mendocino National Forest conducted under funding from the US Forest Service. In Alder Springs, net emissions of 26.3 tons of carbon dioxide per acre were recorded immediately after treatment climbing to a total of 86.9 t CO₂-e/ac after 60 years.

The results from this study in combination with the paired study in Shasta County and the allied study in Mendocino National Forest underline the unsuitability of fuels treatment as a potential greenhouse gas offset generating activity. Instead we argue the shift should be made to policies minimizing greenhouse gas emissions from wildfires and from fuel treatments while minimizing wildfire risks to lives, homes and livelihoods in the WESTCARB region.

5.1 Benefits to California

The research questions being explored in Lake County, and the validation and demonstration of new climate change mitigation opportunities, are equally relevant to California's public and private forests. Debates around managing the multiple economic, social and ecosystem benefits of the State's forests, and the need for creative and aggressive approaches to managing catastrophic wildfire at California's wildland-urban interface, have risen to prominence in the media and public consciousness. Moreover wildfire conditions are projected to worsen with global warming (California Energy Commission 2006), making new strategies for managing the fire-prone forests an important climate adaptation as well as climate mitigation opportunity.

Results from the Lake County, Oregon and Shasta County, California¹¹ hazardous fuel reduction pilot activities indicate that hazardous fuels treatments do not represent potential carbon offset projects. A third WESTCARB report¹² discusses in more depth the reasons such projects do not lead to offsets and addresses shortcomings of similar research that has indicated otherwise.

Regardless of these findings, wildfire poses a significant threat to ecosystems, property, and people, and fighting wildfire represents a large investment of resources. Carefully planned and properly implemented hazardous fuels treatments are a critical means of ensuring the safety of nearby communities and the health of forests. In addition, fuels treatments can lead to increased timber

¹¹ Goslee, K., T. Pearson, S. Grimland, S. Petrova, and S. Brown. 2010. *Final Report on WESTCARB Fuels Management Pilot Activities in Shasta County, California*. California Energy Commission, PIER. CEC-500-XXXX-XXX.

¹²Pearson, T., K. Goslee, and S. Brown. 2010. *Emissions and Potential Emission Reductions from Hazardous Fuel Treatments in the WESTCARB Region*. California Energy Commission, PIER. CEC-500-XXXX-XXX.

production and reduced costs of fighting fires. While there may not be an opportunity to reduce wildfire emissions on a project by project basis, it is imperative that sound wildfire preventative strategies continue to be employed in California forests.

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Annex A: Standard Operating Procedures for Fuels Measurements in 2007 See separate attachment.

Annex B: 2010 Long-range Strategy for the Lakeview Federal Stewardship Unit See separate attachment.

Annex C: 20-year Interagency Biomass Supply MOU

See separate attachment.

Annex D: Governor's press release on new biomass plant in Lakeview, OR See separate attachment.

Annex E: Oregon Solutions Declaration of Cooperation

See separate attachment.

Annex F: Governor's Letter of Support for new biomass plant in Lakeview, OR See separate attachment.

Annex G: 2010 Oregon Business report

See separate attachment.

Annex H: Lakeview Stewardship Group CFLRP proposal

See separate attachment.